Advanced Scientific Computing Research

Program Mission

The primary mission of the Advanced Scientific Computing Research (ASCR) program, which is carried out by the Mathematical, Information, and Computational Sciences (MICS) subprogram, is to discover, develop, and deploy the computational and networking tools that enable researchers in the scientific disciplines to analyze, model, simulate, and predict complex physical, chemical, and biological phenomena important to the Department of Energy (DOE). These tools are crucial if DOE researchers in the scientific disciplines are to maintain their world leadership. To accomplish this mission, the program fosters and supports fundamental research in advanced scientific computing – applied mathematics, computer science, and networking – and operates supercomputers, a high performance network, and related facilities. The applied mathematics research efforts provide the fundamental mathematical methods and algorithms needed to model complex physical, chemical, and biological systems. The computer science research efforts enable scientists to efficiently implement these models on the highest performance computers available and to store, manage, analyze, and visualize the massive amounts of data that result. Networking research provides the techniques to link the data producers, e.g., supercomputers and large experimental facilities, with the data consumers, i.e., scientists who need the data.

In fulfilling this primary mission, the ASCR program supports the Office of Science Strategic Plan's goal of providing extraordinary tools for extraordinary science as well as building the foundation for research in support of the other goals of the strategic plan. In the course of accomplishing this mission, the research programs of ASCR have played a critical role in the evolution of high performance computing and networks. The accomplishments of researchers funded by ASCR, which are listed later in this budget, amply demonstrate the world leadership of this program.

In addition to this primary mission, the ASCR program is also responsible for the Laboratory Technology Research subprogram in the Office of Science. The mission of this subprogram is to foster and support high-risk research in the natural sciences and engineering in partnership with the private sector leading to innovative applications relevant to the Nation's energy sector.

The high quality of the research in the entire ASCR program, supporting both of its missions, is continuously evaluated through the use of merit-based peer review and scientific advisory committees.

The research and facilities supported by ASCR are critical to the success of all the missions of the Office of Science (SC) because computational modeling and simulation have become an important contributor to progress in all SC scientific research programs. Modeling and simulation is particularly important for the solution of research problems that are insoluble by traditional theoretical and experimental approaches, hazardous to study in the laboratory, or time-consuming or expensive to solve by traditional means. All of the research programs in the U.S. Department of Energy's Office of Science—in Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, and High Energy and Nuclear Physics—have identified major scientific challenges that can best be addressed through advances in scientific computing.

Advances in computing technologies during the past decade have set the stage for a major step forward in modeling and simulation. By 2005, computers 1,000 times faster than those generally available to the scientific community in 2000, *i.e., terascale* computers (computers that can perform trillions of operations per second, or over one teraflop), will be at hand. However, to deliver on this promise, these increases in "peak" computing power, *i.e.*, the maximum theoretical speed that a computer can attain, must be translated into corresponding increases in the modeling and simulation capabilities of scientific codes. This is a daunting problem that will only be solved by increased investments in *computer software*—the scientific codes for simulating physical phenomena, the mathematical algorithms that underlie these codes, and the computing systems software that enables the use of high-end computer systems. These investments in software research must be made by DOE and other government agencies whose missions depend on high-end computing because technology trends and business forces in the U.S. computer industry have resulted in radically reduced development and production of high-end systems necessary for meeting the most demanding requirements of scientific research. The U.S. computer industry has become focused on the computer hardware and software needs of business applications, which dominate the market, and cannot justify sufficient investments in software research, focused on the computational needs of the scientific community.

An example that shows the dramatic difference between the requirements of scientific computing and business computing is the calculation that won the 1998 Gordon Bell Prize awarded by the Supercomputing 1998 Conference sponsored by the Association for Computing Machinery (ACM) and the Institute of Electrical and Electronic Engineers (IEEE). This calculation resulted from a research project supported by the Mathematical, Information, and Computational Sciences (MICS) subprogram. This calculation, the first to achieve a teraflop on a real scientific application, was undertaken to better understand and predict the magnetic behavior of atoms in a magnetic material. Such calculations are important for understanding the properties of magnetic storage devices, such as computer hard drives, and permanent magnets. The actual calculation that was performed involved a cube of iron approximately two millionths of a centimeter in each dimension containing 1,458 atoms. In order to predict the magnetic behavior of this cube of iron, using the most efficient mathematical tools available today, approximately 30 trillion operations, i.e. additions, subtractions, multiplications and divisions **per atom**, were required. In addition, each atom required 48 megabytes of memory to store critical data. Therefore, the entire calculation required approximately 70 gigabytes of memory and 45 quadrillion (45×10^{15}) operations to complete.

To put this in context, if you could buy a 500Mhz PC with 70 gigabytes of memory (approximately 1000 times the memory on a typical PC), this problem would take approximately 3 years to solve. In addition, while this calculation represents a major scientific advance, to really understand the behavior of materials in real systems, scientists estimate that they need to solve problems with at least 27,000 atoms, almost twenty (20) times larger than this calculation.

In addition to the development of software to address scientific challenges on high performance computers, the Office of Science faces significant challenges in enabling its research community to have effective access to the computational and experimental data resources at its facilities and in enabling geographically-distributed research teams to work effectively together. Many of the DOE facilities produce thousands to millions of gigabytes of data per year that must be managed and analyzed by scientists at universities, government laboratories, and industrial laboratories across the nation, and in some cases across the world. In addition, remote users increasingly need to be able to control experiments from their home institutions. This enables university professors to integrate their research activities at DOE's facilities into their home research and educational activities. In addition, it decreases both the time and cost of performing the research at remote facilities. These geographically-distributed teams of scientists and engineers along with the supporting experimental and computational facilities, tied together with high performance networks are called National Collaboratories. The current technologies that underlie National Collaboratories, many of which were developed by ASCR, only provide support for basic services and must be significantly enhanced to enable collaborative technologies to achieve their full potential as tools for scientists.

In National Collaboratories it is again the scale of the scientific problems that drives SC's need for advances in information technology. For example, the current state of the art in simulations of the earth's climate uses a grid that measures 0.5 degrees of latitude by 0.5 degrees of longitude. A single snapshot of the data from these simulations may contain 300 megabytes of data (over 3,000 times larger than the Netscape home page), and the output of a full simulation may total 75,000 gigabytes (or 75 terabytes). Sharing this data with a distributed scientific team represents a major technical challenge. It should also be noted that there is considerable interest in using grids much finer than 0.5 degrees which corresponds to distances of approximately 50km on a side, (e.g., Washington DC, Baltimore MD, and Frederick MD could be in the same grid element). Again, because of the scale of DOE's requirements, DOE must support significant network and collaboratory research to satisfy its missions. This research complements commercial research investments.

Program Goals

- Maintain world leadership in areas of advanced scientific computing research relevant to the missions of the Department of Energy.
- Integrate the results of advanced scientific computing research into the natural sciences and engineering.
- Provide world-class supercomputer and networking facilities for scientists working on problems that are important to the missions of the Department.
- Integrate and disseminate the results of high-risk research in natural sciences and engineering to the private sector through the Laboratory Technology Research subprogram.

Program Objectives

- *Advance the frontiers of knowledge in advanced scientific computing research.* — Foster research to create new fundamental knowledge in areas of advanced computing research important to the Department, e.g., high performance computing, high speed networks, and software to enable scientists to make effective use of the highest performance computers available and to support National Collaboratories.
- *Apply advanced computing knowledge to complex problems of importance to DOE.* — Promote the transfer of results of advanced scientific computing research to DOE missions in areas such as the improved use of fossil fuels, including understanding the combustion process; the atmospheric and environmental impacts of energy production and use, including global climate modeling and subsurface transport; and future energy sources, including fusion energy, as well as the fundamental understanding of matter and energy.
- *Plan, construct, and operate premier supercomputer and networking facilities.* — Serve researchers at national laboratories, universities, and industry, thus enabling new understanding through analysis, modeling, and simulation of complex natural and engineered systems and effective integration of geographically distributed teams through national collaboratories.
- *Transfer results of fundamental research to the private sector.* — Provide tangible results of research and development activities through cost-shared partnerships with industry.

Evaluation of Objectives

The Advanced Scientific Computing Research (ASCR) program evaluates the progress being made toward achieving its scientific and management objectives in a variety of ways. Regular peer review and merit evaluation is conducted for all activities, except those Congressionally mandated, based on procedures set down in 10 CFR 605 for the extramural grant program and under a similar modified process for the laboratory programs and scientific user facilities. Facilities, including the National Energy Research Scientific Computing Center (NERSC) and ESnet, will be operated within budget and successfully meet user needs and satisfy overall SC program requirements. All new projects are selected by peer review and merit evaluation for their scientific excellence. Beginning in FY 2001, the Advanced Scientific Computing Advisory Committee (ASCAC) will provide advice on subprogram portfolios. As part of these evaluations, the international leadership of ASCR's advanced scientific computing research programs will be assessed. Specific performance measures are included within the detailed program justification narratives as appropriate.

The overall quality of the research in the ASCR program will be judged excellent and relevant by external review by peers, and through various forms of external recognition.

Leadership in key ASCR disciplines that are critical to DOE's mission and the Nation will be measured through external review and other mechanisms.

At least 80% of all new research projects supported by ASCR will be peer reviewed and competitively selected, and will undergo regular peer review merit evaluation.

ASCR will keep within 10%, on average, of cost and schedule milestones for upgrades and construction of the scientific user facilities it manages.

The ASCR scientific user facilities will be operated and maintained so that unscheduled operational downtime will be less than 10%, on average, of scheduled operating time. This includes the National Energy Research Scientific Computing Center and ESnet.

Ensure the safety and health of the workforce and members of the public and the protection of the environment in all its program activities.

Significant Accomplishments and Program Shifts

The ASCR program builds on decades of leadership in high performance computing and has many pioneering accomplishments. Building on this long history, principal investigators of the ASCR program have received recognition through numerous prizes awards and honors. A sample of pioneering results, recent accomplishments and current awards is given below.

SCIENCE ACCOMPLISHMENTS

Mathematical, Information and Computational Sciences

- *A Fundamental Problem of Quantum Physics Solved*. For over half a century, theorists tried and failed to provide a complete solution to scattering in a quantum system of three charged particles, one of the most fundamental phenomena in atomic physics. Such interactions are everywhere;

ionization by electron impact, for example, is responsible for the glow of fluorescent lights and for the ion beams that engrave silicon chips. Collaborators at Lawrence Berkeley National Laboratory (LBNL), Lawrence Livermore National Laboratory (LLNL), and the University of California at Davis used NERSC's Cray T3E supercomputer to obtain a complete solution of the ionization of a hydrogen atom by collision with an electron, the simplest nontrivial example of the problem's last unsolved component. Their breakthrough employs a mathematical transformation of the Schroedinger wave equation that makes it possible to treat the outgoing particles as if their wave functions simply vanish at large distances from the nucleus instead of extending to infinity if treated conventionally.

- *Biggest Dataset Ever from Cosmic Microwave Background*. Since ancient times, the geometry of the universe has been a topic of speculation and inquiry. An international team of scientists reported in Nature that the universe is, as Euclid thought, flat. They obtained their results by combining cosmic microwave radiation data collected during an Antarctic balloon flight and extensive analysis, amounting to 50,000 hours of computer time, using NERSC's Cray T3E supercomputer and software written at NERSC. Called BOOMERANG for "Balloon Observations Of Millimetric Extragalactic Radiation And Geophysics," the collaboration includes over two dozen researchers from seven countries. Supercomputers at NERSC, along with software developed there, were crucial to extracting fundamental cosmological parameters from the data, the largest and most precise set of cosmic microwave background (CMB) data yet collected. From the dataset, the BOOMERANG team was able to make the most detailed map of the CMB's temperature fluctuations ever seen. From a CMB map, cosmologists derive a "power spectrum," a curve that registers the strength of these fluctuations on different angular scales, and which contains information on such characteristics of the universe as its geometry and how much matter and energy it contains. The power spectrum derived from the BOOMERANG Antarctic flight data is detailed enough to allow the determination of fundamental cosmic parameters to within a few percent, indicating that the geometry of the universe is flat and that the universe will expand forever. The calculation required would have taken almost six years to complete if run on a desktop personal computer. On the NERSC Cray T3E, processing time over the life of the project totaled less than 3 weeks.

- *Access Grid: A New Collaborative Environment*. Argonne computer scientists have developed a new collaborative environment, the Access Grid, that can be used not just for science and engineering applications but for lectures, seminars, tutorials, and training. An Access Grid comprises a large-format multimedia display system about 18 feet by 6 feet; several video streams (for example, a wide audience shot, a close-up shot of the presenter, a wide area shot of the display screen, and a roving camera) projected onto the display; numerous microphones and speakers; and several computers for audio capture, video capture, control, and display. Each Access Grid "node," or site, involves 3-20 people, providing a compelling new environment far beyond desktop-to-desktop collaborative systems.

- *Parallel Computational Oil Reservoir Simulator*. To meet the Nation's energy needs, the United States oil and gas industry must continue to advance the technology used to extract oil and gas from both new and old fields. Until recently, most drilling and recovery activities were based on past practices that often lacked a sound scientific basis. Computer scientists at Argonne National Laboratory, in collaboration with petroleum engineers at the University of Texas at Austin, have recently developed a software package capable of simulating the flow of oil and gas in reservoirs. These codes, which are based on software tools designed at Argonne, are able to run on a variety of computer platforms, including massively parallel systems with hundreds and even thousands of processors. The software codes will enable the oil and gas industry to lower exploration and drilling costs and enhance the yield of oil from new and old fields alike.

- *Cracking the Chemistry of Nuclear Waste Characterization and Processing*. Many DOE research areas require accurate and efficient calculations of molecular electronic structure (e.g., catalysis, combustion, and chemistry in the environment or atmosphere). However, the single most challenging environmental issue confronting the DOE is the safe and cost-effective management of highly radioactive mixed wastes generated by four decades of nuclear weapons production. Modeling the chemistry of these heavy elements (e.g., the actinides which include uranium and plutonium) present an enormous challenge, since relativistic effects must be included, and these greatly increase the cost and complexity of the calculations. The MICS project, Computational Chemistry for Nuclear Waste Characterization and Processing: Relativistic Quantum Chemistry of Actinides, has developed major new capabilities for understanding actinide processes. The seven institution team created new chemistry codes for massively parallel computers (Pacific Northwest, Argonne, and Lawrence Berkeley National Laboratories; Stevens Institute; Eloret; Ohio State University; and Syracuse University) and formed liaisons with experimental research at four DOE labs (Pacific Northwest, Argonne, Lawrence Berkeley, and Los Alamos). This project broke new ground in a number of areas, implementing several models that include relativistic effects. In addition, new models were developed, that provide a very significant improvement in accuracy over previous approaches. This is the first time that any of these methods are available on massively parallel computers.
- *High Performance Algorithms for Scientific Simulation*. Many problems in science and engineering involve the complex interplay of forces and effects on different time and length scales. Two significant examples of such nonlinear multi-time, multi-scale phenomena are the interaction of the atmosphere and the oceans in the creation of the global climate and the burning of fossil fuels in engines and other devices. The size and complexity of such problems require the development of fast and efficient algorithms and software that can take advantage of the resolution power of today's massively parallel computing platforms. Applied mathematicians at the Lawrence Berkeley National Laboratory, working in collaboration with applied mathematicians at the Lawrence Livermore National Laboratory and New York University, have developed adaptive mesh refinement algorithms capable of automatically redistributing grid points in computational regions where significant physics is occurring over small time scales. At finer and finer length scales the continuous flow solver is replaced by a particle method such as Monte Carlo, thus allowing the researchers to accurately resolve phenomena over a broad range of length and time scales. Applications of this work to the Accelerated Strategic Computing Initiative (ASCI) and Office of Science problems are many, although the primary focus of the research is the accurate simulation of diesel combustion in realistic, three-dimensional geometries. Laboratory and academic researchers are working on this project closely with engineers from Caterpillar and Cummins.
- *Solving Optimization Problems Easily and Inexpensively*. Optimization applications range from designing circuits, to estimating the value at risk of financial institutions, to determining routing patterns on the Internet, to finding energy functions for molecular structures. Argonne researchers (together with Northwestern University) completed a project to attack such problems successfully. The project involves development of a novel environment, called the Network-Enabled Optimization System (NEOS). NEOS allows users to solve optimization problems over the Internet with state-of-the-art software without downloading and linking code. Given the definition of a nonlinear optimization problem, NEOS determines an appropriate solver, uses tools to compute derivatives and sparsity patterns, compiles all subroutines, links with the appropriate libraries, and executes the

solver. The user is given a solution in a matter of hours instead of days or weeks. The NEOS project has recently gained considerable visibility with the release of a new portable version that can be run on various computers, Web servers, and email servers. Over the past year, the number of users has risen to an average of 2,600 problem submissions per month. Moreover, NEOS is now being used as an educational tool at universities worldwide. Students and professors alike find it easy to use and have rated it as one of the more efficient ways to access state-of-the-art optimization software.

- *Bringing Powerful Scientific Visualizations to the Desktop*. As part of their work in DOE's Combustion Corridor research project, visualization researchers at Lawrence Berkeley National Laboratory created a new application that will enable distributed scientific visualization of large data volumes on remote workstations. Such visualizations typically represent complex, three-dimensional scientific problems varying over time, such as how two gases mix in a turbulent environment. To visualize these models, researchers previously required access to very powerful computers — moving such large files onto local workstations is either impossible or impractical. The fundamental idea behind Image-Based-Rendering-Assisted Volume Rendering (IBRAVR) is that large data are partially pre-rendered on a large "computational engine" close to the data, with the final image rendering performed on a workstation. The benefits and advantages of the IBRAVR technique include using a new type of visualization and rendering technology which "decomposes" nicely for parallel processing and sharing the workload between a remote multiprocessor machine and a local workstation.
- *Parallel Multigrid Methods*. LLNL researchers, in close collaboration with university colleagues, developed parallel multigrid methods for the solution of large, sparse systems of linear equations. The solution of these large systems (having upwards of one billion unknowns) is often the key computational bottleneck in scientific and engineering application codes. Multigrid is a so-called scalable algorithm, and LLNL's work in this area is already reducing overall simulation times of important LLNL application codes by up to ten-fold (linear solve time is up to 100 times faster than previous solution methods). The largest problem solved by LLNL researchers was a one billion unknown anisotropic diffusion problem, which took just 54 seconds on 3150 processors of the Advanced Strategic Computing Initiative (ASCI) Red platform. These methods are being developed for a variety of different applications, including inertial confinement fusion, structural dynamics, and flow in porous media. The problems of interest are defined on a variety of grids, including structured grids, block-structured grids, adaptive mesh refinement composite grids, overset grids, and unstructured grids. Both geometric and algebraic multigrid techniques are being investigated.
- *Adaptive Laser-Plasma Simulation*. LLNL computational scientists have developed new numerical algorithms and software to enable the use of parallel adaptive mesh refinement in the simulation of laser plasma interaction. The ability to predict and control the interaction of intense laser light with plasmas is critical in the design of laser-driven fusion energy experiments such as those to be conducted at the National Ignition Facility currently under construction at LLNL. These new algorithms solve a system of plasma fluid equations coupled with a laser light propagation model, incorporating parallel adaptive mesh refinement to use fine meshes only where they are needed. This approach has been shown to reduce overall computational requirements ten-fold on certain problems. These novel algorithms have been implemented in a research code called ALPS (Adaptive Laser Plasma Simulator). ALPS solves problems in two or three spatial dimensions and runs on a variety of high performance computing platforms, including massively parallel computers. Substantial speedups relative to conventional uniform grid algorithms has been achieved on problems involving single mode beams and beams smoothed with random phase plates.

FACILITY ACCOMPLISHMENTS

Mathematical, Information and Computational Sciences

- *NERSC Accepts New IBM Supercomputer*. DOE's National Energy Research Scientific Computing Center (NERSC) at Lawrence Berkeley National Laboratory accepted the first phase of its new IBM RS/6000 SP system. As part of the acceptance testing, a group of computational scientists at national laboratories and universities were given early access to the machine to thoroughly test the entire system. Those researchers noted the high performance and ability to scale problems on the IBM SP, which is providing useful scientific results in such areas as climate modeling, materials science, and physics research. The first phase of NERSC's IBM system consists of an RS/6000 SP with 304 POWER3 SMP nodes, each with two processors per node. In all, Phase I has 512 processors for computing, 256 gigabytes of memory and 10 terabytes of disk storage for scientific computing. The system has a peak performance of 410 gigaflops, or 410 billion calculations per second. Phase II, delivered in December 2000, will have 2,048 processors dedicated to large-scale scientific computing and another 384 processors devoted to system tasks. The system will have a peak performance capability of more than 3 teraflops, or 3 trillion calculations per second.
- *ESnet Capability Expanded*. DOE's Energy Sciences Network, known as ESnet, selected Qwest Communications to provide advanced data communications services for the scientific research network. The awarded contract is up to seven years in length, including option years, and is valued at approximately $50,000,000. Under the contract, Qwest will provide a terabit (one million megabits/second) network by the year 2005, offering 500 times the highest speed available on the highest speed networks today. This network will also offer a staggering amount of capacity — more than that of all today's carriers combined.
- *Scientists Install New Testbed for Open Source Software*. A 512-CPU Linux cluster was installed at Argonne's Mathematics and Computer Science Division. The cluster provides a flexible development environment for scalable open source software in four key categories: cluster management, high-performance systems software (file systems, schedulers and libraries), scientific visualization, and distributed computing. Its modular design makes it easily reconfigurable for systems management experiments, and its availability for testing open-source code and algorithms ensures broad use by researchers both within the Laboratory and externally.

AWARDS

Mathematical, Information and Computational Sciences

- *Supercomputing (SC'99) Awards*. Special awards were given to scientists from Argonne National Laboratory and the University of Chicago for their achievements in simulating incompressible flows and another special award was given to a team of scientists from NASA and DOE laboratories for their achievements in fluid dynamics simulations.
- *The Maxwell Prize*. A new international prize in applied mathematics, the Maxwell Prize, has been awarded for MICS supported research at the Applied Mathematics Research program at Lawrence Berkeley National Laboratory. The research involved analysis of problems dominated by complexity, such as turbulence, failure and cracks in solids, flow in porous and inhomogeneous media, and combustion. The work on crack formation provided some of the basic tools used today in failure analysis, especially failure due to fatigue. The prize was awarded by the Committee for International Conferences on Industrial and Applied Mathematics (CICIAM) that is made up of the major applied mathematics organizations in 14 countries.

- *Herbrand 2000 Award*. A senior scientist at Argonne National Laboratory was named recipient of the Herbrand Award for the year 2000. The award is given by the Conference on Automated Deduction Inc. to honor exceptional contributions to the field of automated reasoning. Automated reasoning involves the use of powerful computers to solve the logical (as distinct from the numerical) aspects of problems. Applications range from the design and validation of electronic circuits to assisting in research in mathematics and logic. Only six Herbrand awards have been given in the past decade.
- *An Algorithm for the Ages*. Among the top 10 "Algorithms of the Century" announced by Computing in Science and Engineering magazine is the integer-relation algorithm dubbed PSLQ. PSLQ was discovered by a mathematician at the University of Maryland and implemented in practical computer software by a LBNL researcher. PSLQ has unearthed many surprising relations in mathematics and physics, although its most startling result may well be a simple formula for calculating any binary digit of pi without calculating the digits preceding it. Before PSLQ, mathematicians had not thought that such a digit-extraction algorithm for pi was possible. Using the remarkably simple formula, even a personal computer can calculate pi's millionth binary digit in about 60 seconds. As a tool of experimental mathematics, PSLQ's purpose is to discover new mathematical relations among numbers — for example, constants that occur in various groups of mathematical formulas. Very high precision arithmetic is needed by PSLQ, or else nonsense results are obtained.
- *Global Arrays Power Award Winning Applications*. Supported by the DOE Advanced Computational Testing and Simulation program, Pacific Northwest National Laboratory's Global Array (GA) toolkit provides a unique and portable "shared memory" interface that enables codes to efficiently access massive data structures distributed across thousands of processors. GA also provides easy-to-use interfaces to key numerical libraries, and interoperability with message passing standards like MPI, forming a powerful and complete environment for parallel software development. GA is a critical component of a series of award-winning applications, including Molecular Science Software Suite (MS^3), which was awarded both an R&D-100 award in 1999 and a Federal Laboratory Consortium Technology Transfer award in 2000; and COLUMBUS, featured in the SC'98 Conference Best Overall Paper.
- *Supercomputing (SC 2000) Awards*. Scientists at LBNL won the "Fastest and Fattest" category in the High-Bandwidth Applications Competition for achieving a peak performance of over 1.48 gigabits/second in a prototype application for the visualization of terascale datasets. A team that included members from ANL, LLNL and LBNL won the "Hottest Infrastructure" category for demonstrating secure, high-performance data transfer and replication for large-scale climate modeling data sets. These awards recognize DOE's unique requirements for network services that far exceed usual commercial offerings and DOE's success in solving the significant research problems in networking and applications design to satisfy critical mission requirements.
- *1999 R&D 100 Awards*. Awards were made: to PNNL for the Molecular Science Software Suite (MS3) as the first package to offer advanced computational chemistry components optimized for high-performance massively parallel computers; to ORNL, the University of California at San Diego and the University of Tennessee for Netsolve 1.2, which unifies disparate high-performance computers and software libraries and delivers them as a powerful, easy to use computational service; and to the University of Tennessee and ORNL for ATLAS which automatically generates optimized basic linear algebra subprograms resulting in significant improvements in performance and portability.

The Laboratory Technology Research (LTR) subprogram received one R&D-100 Awards in 2000 for the following research:

- *Carbon Monoxide Monitoring Device.* Lawrence Berkeley National Laboratory (LBNL), in collaboration with Quantum Group, has developed an inexpensive, passive carbon monoxide (CO) occupational dosimeter, which has achieved control of sensor reversibility, humidity dependence, and sensor variability. CO is one of the most deadly environmental pollutants encountered in indoor and outdoor occupational settings. An inexpensive but sensitive and accurate CO monitoring device should help to identify and mitigate high CO environments.

The LTR subprogram received five Federal Laboratory Consortium (FLC) Awards for Excellence in Technology Transfer in 2000 for the following research:

- *Quick, Cost-effective Filler for Potholes.* Argonne National Laboratory, in collaboration with Rostoker, Inc., has developed a versatile, unique, room-temperature technology that uses a nontoxic, nonflammable binder to form products that are impermeable to groundwater and have twice the strength of cement. The technology is filling an important need in the road repair industry as a quick, cost-effective filler for potholes. It also benefits the environment by reducing landfill requirements by encapsulating waste more efficiently than traditional methods.

- *Innovative Purification Method.* LBNL, in collaboration with WaterHealth International, has developed a device that uses readily available, energy-efficient, low-maintenance technologies and materials to disinfect water. For less than 2 cents per metric ton of water, the ultraviolet light from a single 40-watt compact UV bulb disrupts the DNA of contaminating bacteria and viruses within 12 seconds. As of late 1999, about 100,000 people used daily drinking water disinfected by the LBNL device in several developing countries. The children in these countries will now have better survival rates, and more of them will grow up without being stunted from repeated diarrheal episodes.

- *Proton Therapy Used to Treat Cancer.* LBNL, in collaboration with General Atomics, has developed an accelerator-based proton therapy center at Massachusetts General Hospital in Boston to safely destroy cancerous tumors. The recent addition of proton therapy to the arsenal of cancer treatments promises new hope in the battle against the disease. In the U.S. each year, about 375,000 cancer patients use conventional radiation therapy for curative treatments. Of these, about 130,000 patients will benefit if treated with 3D conformal therapy, which is best delivered using proton beams.

- *Superplastic Forming Process for Automotive Components.* Pacific Northwest National Laboratory (PNNL), in collaboration with General Motors and MARC Analysis Research, has significantly reduced the technical and economic impediments to using superplastic forming processes for automotive and other manufacturing. This technology is a metal-forming process that can reduce the weight and cost of manufactured devices such as automotive structural components. Cars with lightweight automotive components that are strong enough to meet design requirements will be safer, more fuel efficient, and have lower emissions.

- *Software to Solve Complex Environmental Problems.* PNNL, in collaboration with DuPont and Amoco, has developed the first general-purpose software that provides chemists with access to high-performance, massively-parallel computers for a wide range of applications. The software is now used by more than 37 universities and supercomputer centers, 14 national laboratories or Federal agencies, and 15 industries. The software will enable the scientific community to quickly and cost-effectively solve complex environmental problems in the atmosphere, aquatic systems, and the subterranean environment.

In addition to the R&D-100 and FLC awards, two scientists supported by the LTR subprogram were recipients of the following distinguished awards in 2000:

- The 1999 Tennessee Industrial Scientist of the Year Award to a group leader in the Metals and Ceramics Division of Oak Ridge National Laboratory.

- The 1999 Battelle Inventor of the Year Award to an analytical biochemist at PNNL.

In FY 2000, the Laboratory Technology Research subprogram initiated a portfolio of Rapid Access Projects that addresses research problems of small businesses by utilizing the unique facilities of the Office of Science laboratories. These projects were selected on the basis of scientific/technical merit and commercial potential, using competitive external peer review.

PROGRAM SHIFTS

The FY 2002 ASCR budget continues the research portfolio enhancements, initiated in FY 2001, to create the next generation of high performance computing and communications tools to support the missions of the Office of Science and the Department of Energy in the next century.

A Federally-chartered advisory committee was established for the Advanced Scientific Computing Research program in FY 2000 and is charged with providing advice on: promising future directions for advanced scientific computing research; strategies to couple advanced scientific computing research to other disciplines; and the relationship of the DOE program to other Federal investments in information technology research. This advisory committee will play a key role in evaluating future planning efforts for research and facilities.

Taking the Next Steps in Scientific Computing, Networking, and Collaboration: Scientific Discovery through Advanced Computing.

In FY 2002, the MICS subprogram of ASCR will continue its components of the collaborative program across the Office of Science to produce the scientific computing, networking and collaboration tools that DOE researchers will require to address the scientific challenges of the next decade. This program was described in the report to Congress entitled, "Scientific Discovery through Advanced Computing," (SciDAC). These enhancements build on the historic strength of the Department of Energy's Office of Science in computational science, computer science, applied mathematics, and high-performance computing and in the design, development, and management of large scientific and engineering projects and scientific user facilities. They also take full advantage of the dramatic increases in computing capabilities being fostered by the *Accelerated Strategic Computing Initiative* (*ASCI*) in the National Nuclear Security Agency (NNSA).

The ASCR contributions to this effort, which are described in detail in the MICS subprogram description, are briefly described below:

1. Continue the competitively selected partnerships focused on discovering, developing, and deploying to scientists key enabling technologies that were initiated in FY 2001. These partnerships, which are

called Integrated Software Infrastructure Centers, play a critical role in providing the software infrastructure that will be used by the SciDAC applications research teams.

2. Continue the integrated program of fundamental research in networking and collaboratory tools, partnerships with key scientific disciplines, and advanced network testbeds to provide the electronic collaboration tools that SciDAC teams, and DOE's next generation of experimental facilities, need to accomplish their goals. These projects were competitively selected in FY 2001.

Interagency Environment

The research and development activities supported by the MICS subprogram are coordinated with other Federal efforts through the Interagency Principals Group, chaired by the President's Science Advisor, and the Information Technology Working Group (ITWG). The ITWG represents the evolution of an interagency coordination process that began under the 1991 High Performance Computing Act as the High Performance Computing, Communications, and Information Technology (HPCCIT) Committee. DOE has been a key participant in these coordination bodies from the outset and will continue to coordinate its R&D efforts closely through this process.

In FY 1999, the President's Information Technology Advisory Committee (PITAC) recommended significant increases in support of basic research in: Software; Scalable Information Infrastructure; High End Computing; Socio-Economic and Workforce Impacts; support of research projects of broader scope; and visionary "Expeditions to the 21st Century" to explore new ways that computing could benefit our world.

Although the focus of the enhanced DOE program is on solving mission critical problems in scientific computing, this program will make significant contributions to the Nation's Information Technology Basic Research effort just as previous DOE mission-related research efforts have led to DOE's leadership in this field. In particular, the enhanced MICS subprogram will place emphasis on software research to improve the performance of high-end computing as well as research on the human-computer interface and on information management and analysis techniques needed to enable scientists to manage, analyze and visualize data from their simulations, and develop effective collaboratories. DOE's program, that focuses on the information technology research needed to enable scientists to solve problems in their disciplines, differs from the National Science Foundation's portfolio, that covers all of information technology. In addition, DOE's focus on large teams with responsibility for delivering software that other researchers can rely on differs from NSF's single investigator focus.

Scientific Facilities Utilization

The ASCR program request includes $28,244,000 in FY 2002 to support the National Energy Research Scientific Computing (NERSC) Center, which is ASCR's component of the SC-wide Scientific Facilities Initiative that started in FY 1996. This investment will provide computer resources for about 2,000 scientists in universities, federal agencies, and U.S. companies. It will also leverage both federally and privately sponsored research, consistent with the Administration's strategy for enhancing the U.S. National science investment. The proposed funding will enable NERSC to maintain its role as one of the Nation's largest, premier unclassified computing centers, which is a critical element in the success of many SC research programs. Research communities that benefit from NERSC include structural biology; superconductor technology; medical research and technology development; materials, chemical, and plasma sciences; high energy and nuclear physics; and environmental and atmospheric research.

Workforce Development

The R&D Workforce Development mission is to ensure the supply of computational and computer science and Ph.D. level scientists for the Department and the Nation through graduate student and post doctoral research support. In FY 2002, this program will support approximately 800 graduate students and post doctoral investigators, of which 500 will be supported at Office of Science user facilities.

ASCR will continue the Computational Science Graduate Fellowship Program with the successful appointment of 20 new students to support the next generation of leaders in computational science.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Advanced Scientific Computing Research					
Mathematical, Information, and Computational Sciences	113,914	160,000	-3,830	156,170	156,170
Laboratory Technology Research	8,424	10,000	-420	9,580	6,880
Subtotal, Advanced Scientific Computing Research	122,338	170,000	-4,250	165,750	163,050
General Reduction	0	-1,732	1,732	0	0
General Reduction for Safeguards and Security	0	-2,153	2,153	0	0
Omnibus Rescission	0	-365	365	0	0
Subtotal, Advanced Scientific Computing Research	122,338 [a] [b]	165,750	0	165,750	163,050
Pending Budget Amendment	0	0	0	0	2,700 [c]
Total, Advanced Scientific Computing Research	122,338	165,750	0	165,750	165,750

Public Law Authorization:

Public Law 95-91, "Department of Energy Organization Act"

Public Law 103-62, "Government Performance and Results Act of 1993"

[a] Excludes $3,041,000 which has been transferred to the SBIR program and $182,000 which has been transferred to the STTR program.

[b] Excludes $2,322,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

[c] A Budget Amendment transferring $2,700,000 from this program will be submitted shortly. The narrative description for this program has already been adjusted to reflect the revised levels.

Funding by Site

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	11,637	5,020	5,020	0	--
Sandia National Laboratories	4,961	3,889	3,889	0	--
Total, Albuquerque Operations Office	16,598	8,909	8,909	0	--
Chicago Operations Office					
Ames Laboratory	1,957	1,668	1,668	0	--
Argonne National Laboratory	12,861	10,447	10,047	-400	-3.8%
Brookhaven National Laboratory	1,847	1,566	1,266	-300	-19.2%
Fermi National Accelerator Laboratory	59	60	60	0	--
Princeton Plasma Physics Laboratory	38	0	0	0	--
Chicago Operations Office	8,760	7,240	7,240	0	--
Total, Chicago Operations Office	25,522	20,981	20,281	-700	-3.3%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	57,069	54,501	54,151	-350	-0.6%
Lawrence Livermore National Laboratory	2,884	3,068	3,068	0	--
Stanford Linear Accelerator Center	590	234	234	0	--
Oakland Operations Office	3,160	960	960	0	--
Total, Oakland Operations Office	63,703	58,763	58,413	-350	-0.6%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science and Education	147	99	99	0	--
Oak Ridge National Laboratory	12,016	10,563	10,223	-340	-3.2%
Thomas Jefferson National Accelerator Facility	49	0	0	0	--
Total, Oak Ridge Operations Office	12,212	10,662	10,322	-340	-3.2%
Richland Operations Office					
Pacific Northwest National Laboratory	2,844	2,038	1,738	-300	-14.7%
Washington Headquarters	1,459	64,397	63,387	-1,010	-1.6%
Subtotal, Advanced Scientific Computing Research	122,338 [a] [b]	165,750	163,050	-2,700	-1.6%
Pending Budget Amendment	0	0	2,700 [c]	+2,700	--
Total, Advanced Scientific Computing Research	122,338	165,750	165,750	0	--

[a] Excludes $3,041,000 which has been transferred to the SBIR program and $182,000 which has been transferred to the STTR program.

[b] Excludes $2,322,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

[c] A Budget Amendment transferring $2,700,000 from this program will be submitted shortly. The narrative description for this program has already been adjusted to reflect the revised levels.

Site Description

Ames Laboratory

Ames Laboratory is a Multiprogram Laboratory located on 10 acres in Ames, Iowa. The MICS subprogram at Ames Laboratory conducts research in the materials scientific application pilot project, which focuses on applying advanced computing to problems in microstructural defects, alloys, and magnetic materials, and in computer science. The LTR subprogram at Ames conducts research in the physical, chemical, materials, mathematical, engineering, and environmental sciences through cost-shared collaborations with industry.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. The MICS subprogram at ANL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. ANL also participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research facility. The testbed at ANL focuses on a large cluster of Intel-based compute nodes with an open source operating system based on LINUX, this cluster has been given the name of "Chiba City." The LTR subprogram at ANL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are chemistry of ceramic membranes, separations technology, near-frictionless carbon coatings, and advanced methods for magnesium production.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The LTR subprogram at BNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are materials for rechargeable lithium batteries, sensors for portable data collection, catalytic production of organic chemicals, and DNA damage responses in human cells.

Fermi National Accelerator Laboratory (Fermilab)

Fermilab is located on a 6,800-acre site about 35 miles west of Chicago, Illinois. The LTR subprogram at Fermilab conducts research in areas such as superconducting magnet research, design and development, detector development and high-performance computing through cost-shared collaborations with industry.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is a Multiprogram Laboratory located in Berkeley, California. The Laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. The MICS subprogram at LBNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. LBNL participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research testbed. The testbed at LBNL currently focuses on very large scale computing on hardware in the T3E architecture from SGI-Cray including issues of distributing jobs over all the processors efficiently and the associated system management issues. LBNL manages the Energy

Sciences Network (ESnet). ESnet is one of the world's most effective and progressive science-related computer networks that provides worldwide access and communications to Office of Science (SC) facilities. In 1996, the National Energy Research Scientific Computing Center (NERSC) was moved from the Lawrence Livermore National Laboratory to LBNL. NERSC provides a range of high-performance, state-of-the-art computing resources that are a critical element in the success of many SC research programs. The LTR subprogram at LBNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are molecular lubricants for computers, advanced material deposition systems, screening novel anti-cancer compounds, and innovative membranes for oxygen separation.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on an 821 acre site in Livermore, California. The MICS subprogram at LLNL involves significant participation in the advanced computing software tools program as well as basic research in applied mathematics.

Los Alamos National Laboratory

Los Alamos National Laboratory (LANL) is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. The Mathematical Information and Computational Sciences (MICS) subprogram at LANL conducts basic research in the mathematics and computer science and in advanced computing software tools. LANL also participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research testbed. The testbed at LANL focuses on a progression of technologies from SGI – Cray involving Origin 2000 Symmetric Multiprocessor Computers linked with HiPPI crossbar switches. This series of research computers has been given the name "Nirvana Blue."

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on 150 acres in Oak Ridge, Tennessee. ORISE provides support for education activities funded within the ASCR program.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The MICS subprogram at ORNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools.

ORNL also participates in several scientific application and collaboratory pilot projects. The LTR subprogram at ORNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are high temperature superconducting wires, microfabricated instrumentation for chemical sensing, and radioactive stents to prevent reformation of arterial blockage.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The MICS subprogram at PNNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. PNNL also participates in several scientific application pilot projects. The LTR subprogram at PNNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are mathematical simulations of glass production, interactions of biological polymers with model surfaces, and characterization of microorganisms in environmental samples.

Princeton Plasma Physics Laboratory

The Princeton Plasma Physics Laboratory (PPPL), a laboratory located in Plainsboro, New Jersey, is dedicated to the development of magnetic fusion energy. The LTR subprogram at PPPL conducts research in areas that include the plasma processing of semiconductor devices and the study of beam-surface interactions through cost-shared collaborations with industry.

Sandia National Laboratories

Sandia National Laboratories (SNL) is a Multiprogram Laboratory, with a total of 3,700 acres, located in Albuquerque, New Mexico, with sites in Livermore, California, and Tonopah, Nevada. The MICS subprogram at SNL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. SNL also participates in several scientific application and collaboratory pilot projects.

Stanford Linear Accelerator Center

The Stanford Linear Accelerator Center (SLAC) is located at the edge of Silicon Valley in California about halfway between San Francisco and San Jose on 426 acres of Stanford University land. The LTR subprogram at SLAC conducts research in areas such as advanced electronics, large-scale ultra-high vacuum systems, radiation physics and monitoring, polarized and high-brightness electron sources, magnet design and measurement, and controls systems through cost-shared collaborations with industry.

Thomas Jefferson National Accelerator Facility

The Thomas Jefferson National Accelerator Facility (TJNAF) is a basic research laboratory located on a 200 acre site in Newport News, Virginia. The LTR subprogram at the TJNAF conducts research in such areas as accelerator and detector engineering, superconducting radiofrequency technology, speed data acquisition, and liquid helium cryogenics through cost-shared collaborations with industry.

All Other Sites

The ASCR program funds research at 71 colleges/universities located in 24 states supporting approximately 117 principal investigators. Also included are funds for research awaiting distribution pending completion of peer review results.

A number of Integrated Software Infrastructure Centers will be established at laboratories and/or universities. Specific site locations will be determined as a result of competitive selection. These centers will focus on specific software challenges confronting users of terascale computers.

Mathematical, Information, and Computational Sciences

Mission Supporting Goals and Objectives

The Mathematical, Information, and Computational Sciences (MICS) subprogram is responsible for carrying out the primary mission of the ASCR program: discovering, developing, and deploying advanced scientific computing and communications tools and operating the high performance computing and network facilities that researchers need to analyze, model, simulate, and — most importantly — predict the behavior of complex natural and engineered systems of importance to the Office of Science and to the Department of Energy. The MICS subprogram supports fundamental research and research facilities in all of the areas in which MICS supports research:

- *Applied Mathematics*. This includes research on the underlying mathematical understanding as well as the numerical algorithms to enable effective description and prediction of physical systems such as fluids, magnetized plasmas, or protein molecules. This includes, for example, methods for solving large systems of partial differential equations on parallel computers, techniques for choosing optimal values for parameters in large systems with hundreds to hundreds of thousands of parameters, improving our understanding of fluid turbulence, and developing techniques for reliably estimating the errors in simulations of complex physical phenomena.
- *Computer Science*. This includes research in computer science to enable large scientific applications through advances in massively parallel computing, such as very lightweight operating systems for parallel computers, distributed computing such as development of the Parallel Virtual Machine (PVM) software package that has become an industry standard, and large scale data management and visualization. The development of new computer and computational science techniques will allow scientists to use the most advanced computers without being overwhelmed by the complexity of rewriting their codes every 18 months.
- *Networking*. This includes research in high performance networks and information surety required to support high performance applications – protocols for high performance networks, methods for measuring the performance of high performance networks, and software to enable high speed connections between high performance computers and networks, and scalable methods for providing scientific users of networks the security services they need. The information security and assurance research supported by MICS is focused on the requirements of scientists engaged in unclassified research for applications such as remote control of experimental devices and research collaborations. The development of high-speed communications and collaboration technologies will allow scientists to view, compare, and integrate data from multiple sources remotely.

MICS also operates supercomputer and network facilities that are available to researchers 24 hours a day, 365 days a year. The computing and networking requirements of the Office of Science far exceed the current state-of-the-art; furthermore, the requirements far exceed the tools that the commercial marketplace will deliver. For this reason, the MICS subprogram must not only support basic research in the areas listed above, but also the development of the results from this basic research into software usable by scientists in other disciplines and partnerships with users to test the usefulness of the research. These partnerships with the scientific disciplines are critical because they provide rigorous tests of the usefulness of current advanced computing research, enable MICS to transfer the results of this research to scientists in the disciplines, and help define promising areas for future research. This integrated approach is critical for MICS to succeed in providing the extraordinary computational and communications tools that DOE's civilian programs need to carry out their missions. It is important to note that these tools have applications beyond the Office of Science in the NNSA and in the private sector after they have been initially discovered and developed by MICS.

As noted earlier, in FY 2002, the MICS subprogram will continue its components of the collaborative SciDAC program across the Office of Science to produce the scientific computing, networking and collaboration tools that DOE researchers will require to address the scientific challenges of the next decade. The MICS components include investments in scientific computing research and networking and collaboration research that are complemented by investments in computing and networking facilities.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health. In addition, **performance will be measured by** serving researchers at national laboratories, universities, and industry, thus, enabling new understanding through analysis, modeling and simulation of complex natural and engineered systems and effective integration of geographically distributed teams through national collaboratories.

Scientific Computing Research Investments

As noted earlier, advances in computing technologies during the past decade have set the stage for a major step forward in modeling and simulation. The key measure of success in translating peak computing power into science is the percent of peak performance that is delivered to an application over the *entire* calculation. In the early to mid-1990's on computers such as the Cray Research C-90, many scientific codes realized 40% to 50% of the peak performance of the supercomputer. In contrast, on today's parallel supercomputers, scientific computing codes often realize only 5% to 10% of "peak" performance, and this fraction could decrease as the number of processors in the computers grows.

This challenge is a direct result of the fact that the speed of memory systems and the speed of interconnects between processors is increasing much more slowly than processor speed. For many scientific applications these factors dominate the performance of the application. Two types of solutions are available to the computer hardware designer in addressing the mismatch of speed between the components: (1) clever hierarchical arrangements of memory with varying speeds and software to find data before it is needed and move it into faster memory, closer to the processor that will need it; and (2) techniques to increase parallelism, for example, by using threads in the processor workloads or by combining parallel data streams from memory or disks. Current technology forecasts indicate a doubling or quadrupling in the numbers of layers in the memory hierarchy, and a 100- to 1000-fold increase in the amount of parallelism in disk and tape systems to accommodate the relative increase in the mismatch between processor speed and memory, disk and tape speeds in the next five years.

One result of this increasing complexity of high-performance computer systems is the importance of the underlying systems software. Operating systems, compilers, runtime environments, mathematical libraries, and end-user applications must all work together efficiently to extract the desired high performance from these systems.

In addition to the challenges inherent to managing the required level of parallelism, technology trends and business forces in the U.S. computer system industry have resulted in radically reduced development and production of high-end systems necessary for meeting the most demanding requirements of scientific research. In essence, the U.S. computer industry has become focused on the computer hardware and software needs of business applications, and little attention is paid to the special computational needs of the scientific community. Therefore, to achieve the performance levels required for agency missions and world leadership in computational science, large numbers of smaller commercial systems must be combined and integrated to produce terascale computers. Unfortunately, the operating systems software and tools required for effective use of these large systems are significantly different from the technology offered for the individual smaller components. Therefore, new enabling software must be developed if scientists are to take advantage of these new computers in the next five years.

The following are specific examples of *computer science* research challenges:

- Efficient, high-performance operating systems, compilers, and communications libraries for high-end computers.
- Software to enable scientists to store, manage, analyze, visualize, and extract scientific understanding from the enormous (terabyte to petabyte) data archives that these computers will generate.
- Software frameworks that enable scientists to reuse most of their intellectual investment when moving from one computer to another and make use of lower-level components, such as runtime services and mathematical libraries, that have been optimized for the particular architecture.
- Scalable resource management and scheduling software for computers with thousands of processors.
- Performance monitoring tools to enable scientists to understand how to achieve high performance with their codes.

In addition to these computer science challenges, significant enhancements to the MICS applied mathematical research activity are required for the Department to satisfy its mission requirements for computational science. Over the history of computing, improvements in algorithms have yielded at least as much increase in performance as has hardware speedup. Large proportions of these advances are the products of the MICS applied mathematics research activity. In addition to improving the speed of the calculations, many of these advances have dramatically increased the amount of scientific understanding produced by each computer operation. For example, a class of mathematical algorithms called “fast multipole algorithms,” were discovered for a number of important mathematical operations required to process 1,000 datapoints by a factor of 1,000; 10,000 datapoints by a factor of 10,000; and so on. Another example of how powerful these methods can be is that they enable a scientist to process 10,000 datapoints in the time that it would have taken to process 100 using earlier techniques, or 1,000,000 datapoints in the time older techniques would have needed to process 1,000. The requirements of scientific domains for new algorithms that can scale to work effectively across thousands of processors and produce the most science in the fewest number of computer operations drives the need for improved mathematical algorithms and the supporting software libraries that must be made available for ready use by domain scientists. In this area of research the MICS applied mathematics activity is the core of the nationwide effort.

The MICS subprogram will address these challenges by continuing the competitively selected partnerships (based on a solicitation notice to labs and universities) focused on discovering, developing, and deploying to scientists key enabling technologies that were initiated in FY 2001. These partnerships, which are called Integrated Software Infrastructure Centers, must support the full range of activities from basic research through deployment and training because the commercial market for software to support terascale scientific computers is too small to be interesting to commercial software providers. These centers play a critical role in providing the software infrastructure that will be used by the SciDAC applications research teams. The management of these centers will build on the successful experience of the MICS subprogram in managing the DOE2000 initiative, as well as on the lessons learned in important programs supported by DARPA such as Project Athena at MIT, the Berkeley Unix Project, and the initial development of the Internet software and the Internet Activities Board (IAB). These Integrated Software Infrastructure Centers will have close ties to key scientific applications projects to ensure their success.

The efforts initiated in FY 2001 address the important issues of understanding and developing the tools that applications developers need to make effective use of machines that will be available in the next several years.

The MICS activities that respond to these challenges are described later in the Detailed Program Justification section of the MICS subprogram budget under the headings:

Applied Mathematics,

Computer Science, and

Advanced Computing Software Tools.

Networking and Collaboration Research Investments

Advances in network capabilities and network-based technologies now make it possible for large geographically distributed teams to effectively collaborate on the solution of complex problems. This is especially important for the teams using the major experimental facilities, computational resources, and data resources supported by DOE.

- Significant research is needed to enable today's Internet to be effectively used for scientific data retrieval and analysis and collaboratories. The requirements this places on the network are very different than the requirements of the commercial sector where millions of users are moving to small web pages. The MICS subprogram includes research on advanced protocols, special operating system services to support very high-speed transfers, and advanced network control.
- Research is also needed to understand how to integrate the large number of network devices, network-attached devices, and services that collaboratories require. Examples of the components and services that need to be integrated include network resources, data archives on tape, high

performance disk caches, visualization and data analysis servers, authentication and security services, and the computer on a scientist's desk. Common software framework building blocks or "middleware" to enable the collaboratories of the future to succeed must tie all of these physical and software services together.

The MICS subprogram will address these challenges through an integrated program of fundamental research in networking and collaboratory tools, partnerships with key scientific disciplines, and advanced network testbeds.

The MICS activities that respond to these challenges are described in the Detailed Program Justification section of the MICS subprogram budget under the headings:

Networking,

Collaboratory Tools, and

National Collaboratory Pilot Projects.

Enhancements to Computing and Networking Facilities

To realize the scientific opportunities offered by advanced computing, enhancements to the Office of Science's computing and networking facilities are also required. The MICS subprogram supports a suite of high-end computing resources and networking resources for the Office of Science:

- **Production High Performance Computing Facilities.** The National Energy Research Scientific Computing Center (NERSC) provides high performance computing for investigators supported by the Office of Science. NERSC provides a spectrum of supercomputers offering a range of high performance computing resources and associated software support.
- **Energy Sciences Network (ESnet).** ESnet provides worldwide access to Office of Science facilities, including light sources, neutron sources, particle accelerators, fusion reactors, spectrometers, high-end computing facilities and other leading-edge instruments and facilities.
- **Advanced Computing Research Testbeds.** These testbeds provide advanced computational hardware for testing and evaluating new computing hardware and software. In addition, these testbeds will provide specialized computational resources to support SciDAC applications teams in FY 2002.

Current production resources provide less than half of the computer resources that were requested last year. The pressure on production facilities will only increase in future years as more applications become ready to move from testing the software to using the software to generate new science. In addition, as the speed of computers increases, the amount of data they produce also increases. Therefore, focused enhancements to the Office of Science's network infrastructure are required to enable scientists to access and understand the data generated by their software. These network enhancements are also required to allow researchers to have effective remote access to the experimental facilities that the Office of Science provides for the Nation.

The MICS activities that respond to these challenges are described later in the Detailed Program Justification section of the MICS subprogram budget under the headings:

National Energy Research Scientific Computing Center (NERSC),
Advanced Computing Research Testbeds, and
Energy Sciences Network (ESnet).

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Mathematical, Computational, and Computer Sciences Research	42,713	70,654	70,681	+27	--
Advanced Computation, Communications Research and Associated Activities	71,201	81,543	81,543	0	--
SBIR/STTR	0	3,973	3,946	-27	-0.7%
Total, Mathematical, Information, and Computational Sciences	113,914	156,170	156,170	0	--

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
Mathematical, Computational, and Computer Sciences Research	**42,713**	**70,654**	**70,681**
Applied Mathematics	**20,391**	**32,339**	**32,366**

Research is conducted on the underlying mathematical understanding and numerical algorithms to enable effective description and prediction of physical systems. Research in applied mathematics is critical to the DOE because of the potential of improved mathematical techniques to enable large computational simulations. As discussed earlier in the ASCR overview, improvements in mathematical algorithms are responsible for greater improvement in scientific computing capabilities than the increases in hardware performance. This activity supports research at DOE laboratories, universities, and private companies at a level similar to previous years. Many of the projects supported by this activity are partnerships between researchers at universities and DOE laboratories. To accomplish its goals, the program supports research in a number of areas including: ordinary and partial differential equations, including numerical linear algebra, iterative methods, sparse solvers, and dense solvers; fluid dynamics, including compressible, incompressible and reacting flows, turbulence modeling, and multiphase flows; optimization, including linear and nonlinear programming, interior-point methods, and discrete and integer programming; mathematical physics, including string theory, superstring theory, geometry of space-time, and quantum effects; control theory, including differential-algebraic systems, order

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

reduction, queuing theory; shock wave theory systems, multipole expansions, mixed elliptic-hyperbolic problems, including hyperbolic and wavelet transforms; dynamical systems, including chaos-theory and control, and bifurcation theory; programming; and geometric and symbolic computing, including minimal surfaces and automated theorem proving.

The FY 2002 budget continues the FY 2001 increased level of funding for the Computational Sciences Graduate Fellowship program and the competitively selected Integrated Software Infrastructure Centers (ISICs) partnerships focused on algorithms and mathematical libraries for critical DOE applications on terascale computers that are a significant component of the SciDAC program.

Performance will be measured in a number of ways. Efforts in applied mathematics will be continuously evaluated for their leadership and significant contributions to the worldwide applied mathematics effort using a number of measures including awards, significant advances, and invited participation and membership on organizing and program committees of major national and international conferences. Progress reviews of the Integrated Software Infrastructure Centers (ISICs) will be conducted to ensure that these partnerships are moving forward to accomplish their missions. The Computational Science Graduate Fellowship Program will appoint 20 new students to develop the next generation of leaders in computational science for DOE and the Nation.

	FY 2000	FY 2001	FY 2002
Computer Science	**13,747**	**21,051**	**21,051**

Research in computer science to enable large scientific applications is critical to DOE because its unique requirements for high performance computing significantly exceed the capabilities of computer vendors' standard products. Therefore, much of the computer science to support this scale of computation must be developed by DOE. This activity supports research in two general areas: the underlying software to enable applications to make effective use of computers with hundreds or thousands of processors as well as computers that are located at different sites; and large scale data management and visualization under circumstances where the underlying resources and users are geographically distributed. The first area includes research in protocols and tools for interprocessor communication and parallel input/output (I/O) as well as tools to monitor the performance of scientific applications and advanced techniques for visualizing very large-scale scientific data. Researchers at DOE laboratories and universities, often working together in partnerships, carry out this research. In FY 2002, support for the competitively selected Integrated Software Infrastructure Centers to address critical computer science and systems software issues for terascale computers will be continued. The teams in these Centers focus on critical issues including: tools for analyzing and debugging scientific simulation software that uses thousands of processors; and the development of data management and visualization software capable of handling terabyte scale data sets extracted from petabyte scale data archives. These Integrated Software Infrastructure Centers are a critical component in DOE's strategy for SciDAC.

Performance in computer science will be measured through peer review, periodic external expert review of ongoing projects, production of significant research results, and adoption of these technologies by other researchers supported by the Office of Science. In addition, the ISICs initiated in FY 2001 will undergo a progress review to ensure effective coupling both between the ISICs, and between the ISICs and application teams in the MICS Scientific Applications Pilot Projects efforts and with the SciDAC teams funded by the other Programs in the Office of Science.

	FY 2000	FY 2001	FY 2002
Advanced Computing Software Tools	**4,910**	**8,473**	**8,473**

This research uses the results of fundamental research in applied mathematics and computer science to develop an integrated set of software tools that scientists in various disciplines can use to develop high performance applications (such as simulating the behavior of materials). These tools, that provide improved performance on high-end systems, are critical to the ability of scientists to attack the complex scientific and engineering problems that can only be solved with high-end computing systems. The initial goal of this program element was to develop foundational tools (math libraries, runtime systems, etc.) that will have a useful life spanning many generations of computer hardware. From the experience gained with end user application scientists applying these tools, it has become clear that to promote wide usage across the scientific community, the tools must also be reliable, documented, and easy to use. In addition, users of the tools need the tools to be maintained so that the tools continue to be available, have bugs fixed, etc. Since many of the tools needed in the high performance arena have no commercial market, the Integrated Software Infrastructure Centers initiated in FY 2001 will provide a means for focused investment to deploy these tools to the scientific community. These competitively selected centers focus research in several areas that include software frameworks, problem-solving environments, distributed computing and collaboration technologies, as well as visualization and data management.

Performance will be measured through peer review, periodic external expert review of ongoing projects, production of significant research results, and adoption of these technologies by other researchers in the Office of Science. In addition, the ISICs initiated in FY 2001 will undergo a progress review to ensure effective coupling between the ISICs and between the ISICs and application teams in the MICS Scientific Applications Pilot Projects efforts and in the SciDAC teams funded by the other Programs in the Office of Science.

	FY 2000	FY 2001	FY 2002
Scientific Applications Pilot Projects	**3,665**	**8,791**	**8,791**

This research is a collaborative effort with disciplinary computational scientists to apply the computational techniques and tools developed by MICS supported research to basic research problems relevant to the mission of SC. This effort tests the usefulness of current advanced computing research, transfers the results of this research to the scientific disciplines, and helps define promising areas for future research. The FY 2002 funding for this activity will allow the continuation of the pilot projects that were competitively selected in FY 2001. These pilot projects are tightly coupled to the Integrated Software Infrastructure Centers (described above in applied

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

mathematics, computer science and advanced computing software tools) to ensure that these activities are an integrated approach to the challenges of terascale simulation and modeling that DOE faces to accomplish its missions.

Advanced Computation, Communications Research, and Associated Activities	**71,201**	**81,543**	**81,543**
Networking	**5,892**	**7,066**	**7,066**

Research is needed to develop high-performance networks that are capable of supporting distributed high-end computing and secure large-scale scientific collaboration. High performance networks enable scientists to collaborate effectively and to have efficient access to distributed computing resources such as tera-scale computers, and experimental scientific instruments, and large scientific data archives. This research is carried out at national laboratories and universities. It focuses in areas such as high-performance transport protocols for high-speed networks; scalable techniques for measuring, analyzing, and controlling traffic in high performance networks; network security research to support large-scale scientific collaboration; advanced network components to enable high-speed connections between terascale computers, large scientific data archives, and high-speed networks; and research on high-performance "middleware." Middleware is a collection of network-aware software components that scientific applications need in order to couple efficiently to advanced network services and make effective use of experimental devices, data archives, and terascale computers at different locations. In all of these cases, the network and middleware requirements of DOE significantly exceed those of the commercial market.

Collaboratory Tools	**2,946**	**5,527**	**5,527**

This research uses the results of fundamental research in computer science and networking to develop an integrated set of software tools to support scientific collaborations. This includes enabling scientists to remotely access and control facilities and share data in real time, and to effectively share data with colleagues throughout the life of a project. These tools provide a new way of organizing and performing scientific work that offers the potential for increased productivity and efficiency. These tools will also enable broader access to important DOE facilities and data resources by scientists and educators across the country. This research includes, for example, developing and demonstrating an open, scalable approach to application-level security in widely distributed, open network environments that can be used by all the collaboratory tools as well as by the advanced computing software tools whenever access control and authentication are issues. Having demonstrated feasibility of the security architecture on a small scale, an additional investment is needed to support the integration of collaboratory tools with advanced networking services in a research setting. In this way, security features can be integrated into more end user applications or collaboratory tools, and demonstrated on a large user base. An example of research in collaboratory tools is the development of a modular electronic notebook that extends the capabilities of its paper counterpart by allowing scientists located across the country to share a common record of ideas, data and events of their joint experiments and research programs. These are designed to be valid as a long term, legally defensible record of research,

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

invention, and records management. Tools are being developed for managing distributed collaborations where videoconferencing, whiteboards, and other shared applications are important. Software to enable geographically distributed teams to collaboratively control visualization of data is also being investigated.

National Collaboratory Pilot Projects	**4,910**	**10,857**	**10,857**

This program is intended to test, validate, and apply collaboratory tools in real-world situations in partnership with other DOE programs. The competitively selected partnerships involve national laboratories, universities, and U.S. industry. It is important to continue to demonstrate and test the benefits of collaboratory tools technology in order to promote its widespread use and enable more effective access to the wide range of resources within the Department, from light sources to terascale computers to petabyte data storage systems. The partnerships that were initiated in FY 2001 focus on developing user environments where collaboration is ubiquitous and distributed computing is seamless and transparent for DOE mission applications such as High Energy and Nuclear Physics data as well as remote analysis and visualization of experimental and simulation results. This level of funding will permit the continuation of the efforts funded in FY 2001.

National Energy Research Scientific Computing Center (NERSC)	**26,252**	**28,244**	**28,244**

NERSC, located at LBNL, provides high performance computing for investigators supported by the Office of Science. The Center serves 2,000 users working on about 700 projects; 35 percent of users are university based, 60 percent are in National Laboratories, and 5 percent are in industry. NERSC provides a spectrum of supercomputers offering a range of high performance computing resources and associated software support. The two major computational resources at NERSC are a 512 processor Cray T3E computer and a large IBM SP computer whose initial installation was completed in early FY 2000 in a fully competitive procurement process. The FY 2002 funding will support the operation of the IBM-SP computer at about 3.5 teraflops "peak" performance. These computational resources will be integrated by a common high performance file storage system that facilitates interdisciplinary collaborations. Related requirements for capital equipment, such as high-speed disk storage systems, archival data storage systems, and high performance visualization hardware, and general plant projects (GPP) funding are also supported. The MIE for the distributed visualization server was completed in FY 2001. FY 2002 capital equipment requirements continue at the same level as in FY 2001; however, no individual anticipated capital purchase exceeds the MIE threshold.

Performance will be measured in a number of ways. The operating time lost due to unscheduled NERSC downtime, which will be less than 10 percent of the total scheduled possible operating time. In addition, user surveys will continue to show a high degree of satisfaction with the services at NERSC and annual reports will continue to demonstrate production of world-class

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

science from the facility. In FY 2000, the measured operating time lost to unscheduled downtime on systems at NERSC ranged from .08% to .52% of total scheduled possible operating time. NERSC will be operated within budget while meeting user needs and satisfying overall SC program requirements.

Advanced Computing Research Testbeds	**15,739**	**13,061**	**13,061**

This activity supports the advanced computational hardware testbeds that play a critical role in testing and evaluating new computing hardware and software, especially with regard to their applicabilities to scientific problems. Current testbeds are located at Argonne National Laboratory (IBM/ Intel Cluster); and ORNL (Compaq-Alpha technology). These testbeds represent the evolution of Advanced Computing Research Facilities that supported the computational requirements of the scientific application partnerships that were completed in FY 2000. Support for the Nirvana Blue Computer Testbed at LANL was phased out in FY 2001. This activity also supports the distributed high performance storage system (HPSS) testbed collaboration between ORNL and LBNL. Because many of the issues to be investigated only appear in the computer systems at significantly larger scale than the computer manufacturers' commercial design point, these testbeds must procure the largest scale systems that can be afforded and develop software to manage and make them useful. In addition, the ACRTs, taken together, must have a full range of computer architectures to enable comparison and reduce overall program risk. These all involve significant research efforts, often in partnership with the vendors to resolve issues including operating system stability and performance, system manageability and scheduling, fault tolerance and recovery, and details of the interprocessor communications network. Therefore, these systems are managed as research programs and not as information technology investments. In addition, these testbeds will provide specialized computational resources to support SciDAC applications teams in FY 2002.

Performance will be measured by the importance of the research that results from these testbeds as viewed by publications in the scientific literature, the ASCR Advisory Committee and external reviews and the demand for access to these facilities by the nationwide computer and computational science communities.

Energy Sciences Network (ESnet).......................................	**15,462**	**16,788**	**16,788**

ESnet provides worldwide access to the Office of Science facilities, including: advanced light sources; neutron sources; particle accelerators; fusion reactors; spectrometers; supercomputers; Advanced Computing Research Testbeds (ACRTs); and other leading-edge science instruments and facilities. ESnet provides the communications fabric that links worldwide DOE researchers to one another and forms the basis for fundamental research in networking, enabling R&D in collaboratory tools, and applications testbeds such as the national collaboratory pilot projects. To provide these facilities, DOE employs ESnet management at LBNL, who contracts with commercial vendors for advanced communications services including Asynchronous Transfer Mode (ATM) and Wave Division Multiplexing (WDM). LBNL ESnet management provides system integration to provide a uniform interface to these services for DOE laboratories. In

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

addition, LBNL ESnet management is responsible for the interfaces between the network fabric it provides and the worldwide Internet including the University Corporation for Advanced Internet Development (UCAID) Abilene network that provides high performance connections to many research universities. One reason that ESnet, in the words of the 1998 external review committee, is able to provide the capabilities and services to its users "at significantly lower budgets than other agencies" is its management structure with strong user and site coordination committees. This management structure is built on DOE's experience in operating large user facilities. The funding in FY 2002 will continue support for an advanced network testbed established in FY 2001 to enable research in collaboratory tools and pilots. Related capital equipment needs are also supported such as high-speed network routers, ATM switches, and network management and testing equipment.

Performance will be measured in a number of ways. The operating time lost due to unscheduled ESnet downtime will be less than 10 percent of the total scheduled possible operating time. In addition, the ESnet program will be reviewed by an external committee during FY 2001 to ensure its effectiveness in meeting its goals. In FY 2000, the measured operating time lost to unscheduled downtime on ESnet was 4 percent of total scheduled possible operating time. ESnet will operate within budget while meeting user needs and satisfying overall SC program requirements. Network enhancements improve researchers access to high performance computing and software support, and enhance scientific opportunities by enabling scientists to access and understand greater amounts of scientific data.

	FY 2000	FY 2001	FY 2002
SBIR/STTR	**0**	**3,973**	**3,946**

In FY 2000, $2,821,000 and $169,000 were transferred to the SBIR and STTR programs, respectively. The FY 2001 and FY 2002 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.

	FY 2000	FY 2001	FY 2002
Total, Mathematical, Information, and Computational Sciences	**113,914**	**156,170**	**156,170**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Mathematical, Computational, and Computer Sciences Research	
Provides a slight increase for the competitively selected Integrated Software Infrastructure Centers (ISICs) partnerships focused on algorithms and mathematical libraries for critical DOE applications on terascale computers that are a significant component of the SciDAC program.	+27
SBIR/STTR	
Decrease in SBIR/STTR due to decrease in operating expenses.	-27
Total Funding Change, Mathematical, Information, and Computational Sciences	0

Laboratory Technology Research

Mission Supporting Goals and Objectives

The mission of the Laboratory Technology Research (LTR) subprogram is to support high risk research that advances science and technology to enable applications that could significantly impact the Nation's energy economy. LTR fosters the production of research results motivated by a practical energy payoff through cost-shared collaborations between the Office of Science (SC) laboratories and industry.

An important component of the Department's strategic goals is to ensure that the United States maintains its leadership in science and technology. LTR is the lead program in the Office of Science for leveraging science and technology to advance understanding and to promote our country's economic competitiveness through cost-shared partnerships with the private sector.

The National Laboratories under the stewardship of the Office of Science conduct research in a variety of scientific and technical fields and operates unique scientific facilities. Viewed as a system, these ten laboratories — Ames Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Princeton Plasma Physics Laboratory, Stanford Linear Accelerator Center, and Thomas Jefferson National Accelerator Facility — offer a comprehensive resource for research collaborations. The major component of the LTR research portfolio consists of investments at these laboratories to conduct research that benefits all major stakeholders — the DOE, the industrial collaborators, and the Nation. These investments are further leveraged by the participation of an industry partner, using Cooperative Research and Development Agreements (CRADAs). Another LTR subprogram component provides funding to the Office of Science national laboratories to facilitate rapid access to the research capabilities at the SC laboratories through agile partnership mechanisms including personnel exchanges and technical consultations with small business. The LTR subprogram currently emphasizes three critical areas of DOE mission-related research: advanced materials processing and utilization, nanotechnology, intelligent processes and controls, and energy-related applications of biotechnology.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Laboratory Technology Research..........	8,424	9,326	6,698	-2,628	-28.2%
SBIR/STTR	0	254	182	-72	-28.3%
Total, Laboratory Technology Research..	8,424	9,580	6,880	-2,700	-28.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Laboratory Technology Research..	**8,424**	**9,326**	**6,698**

This activity supports research to advance the fundamental science at the Office of Science (SC) laboratories toward innovative energy applications. Through CRADAs, the SC laboratories enter into cost-shared research partnerships with industry, typically for a period of three years, to explore energy applications of research advances in areas of mission relevance to both parties. The research portfolio consists of 45 projects and emphasizes the following topics: advanced materials processing and utilization, nanotechnology, intelligent processes and controls, and energy-related applications of biotechnology. Efforts underway include the exploration of: (1) a new mask-less photoelectrochemical method for depositing conductive metal patterns with nanometer-scale precision for use in fabricating miniaturized and rugged electrical interconnects and biomolecular electronic devices on any surface or in solution; (2) an innovative injector design for a compact, low-cost, high brightness electron gun to be used in linear colliders, short wavelength Free Electron Lasers, and as a test bed for advanced accelerator concepts; and (3) a new design for a compact scintillation camera for medical imaging for use in the detection of thyroid disease and for pre-surgical imaging of breast cancer and nodal metastases. A small but important component of this activity provides industry, particularly small businesses, with rapid access to the unique research capabilities and resources at the SC laboratories. These research efforts are usually supported for a few months to quantify the energy benefit of a specific problem posed by industry. Recent projects supported the development of: (1) Metal Plasma Immersion Ion Implantation and Deposition to produce various layers of reduced size in copper metallization for the next generation of integrated circuits; (2) the optimization of the composition and mechanical properties of new steels for elevated temperature applications used in the power generation, chemical, and petrochemical industries; and (3) infrared thermography and computer modeling of electrical surge arresters which should lead to increased reliability of electrical energy transmission and reduced inconvenience and expense of power outages for end users. The FY 2002 budget will allow the LTR subprogram to continue technology research partnership projects in emerging areas of interest to DOE; however, the number of research projects supported by CRADAs will be reduced by approximately 30 percent from FY 2001. The Rapid Access portion of the LTR subprogram will be preserved.

Performance in this activity will be measured through merit-based peer and on-site reviews.

SBIR/STTR	**0**	**254**	**182**

In FY 2000, $220,000 and $13,000 were transferred to the SBIR and STTR programs, respectively. The FY 2001 and FY 2002 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.

Total, Laboratory Technology Research................................	**8,424**	**9,580**	**6,880**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Laboratory Technology Research	
Decrease the number of supported collaborative research projects by approximately 30 percent.	-2,628
SBIR/STTR	
SBIR/STTR decreases due to decrease in operating expenses.	-72
Total Funding Change, Laboratory Technology Research	-2,700

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects	0	0	1,000	+1,000	+100.0%
Capital Equipment (total)	3,797	6,250	6,250	0	0.0%
Total, Capital Operating Expenses	3,797	6,250	7,250	+1,000	+16.0%

Major Items of Equipment (TEC $2 million or greater)

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2000	FY 2001	FY 2002	Accept-ance Date
Archival Systems Upgrade – LBNL	2,000	0	2,000	0	0	FY 2002
Distributed Visualization Server – LBNL	2,500	0	0	2,500	0	FY 2001
Total, Major Items of Equipment		0	2,000	2,500	0	

Multiprogram Energy Laboratories - Facilities Support

Program Mission

The mission of the Multiprogram Energy Laboratories - Facilities Support (MEL-FS) program is to support the infrastructure of the five Office of Science (SC) multiprogram national laboratories to enable them to conduct today's high technology scientific research. The notable success of the SC multiprogram laboratories in delivering insights and innovations rests on their distinctive technical and scientific expertise and unique capabilities, including the major user facilities. Continued success depends critically on the ability to maintain both the facilities and the expertise, which requires the existence of an adequate, ES&H compliant and cost effective general purpose infrastructure.

The program funds line item construction funding (i.e., projects with a total estimated cost of $5,000,000 or above) for general purpose facilities at Argonne National Laboratory - East (ANL-E), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL). These laboratories are government-owned, contractor-operated (GOCO) and have over 1,600 buildings (including 500 trailers) with 15.5 million gross square feet of space and an estimated replacement value of over $10 billion. Total operating funding for these laboratories is over $3 billion a year.

The program provides Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation. Local communities around ANL-E, BNL, and ORNL qualify for PILT.

The program also supports costs incurred for centralized Oak Ridge Operations Office (ORO) infrastructure requirements and general operating costs essential to maintaining a viable, functioning operations office. Activities include roads and grounds maintenance, infrastructure maintenance, physical security, emergency management, support of the Oak Ridge Financial Service Center and other technical needs related to landlord responsibilities of the ORO.

Program Goals

- To ensure that the general purpose infrastructure at the multiprogram laboratories meets the Department's research needs in a safe, environmentally sound, and cost-effective manner primarily by refurbishing or replacing deteriorated, outmoded, unsafe, and inefficient general purpose infrastructure.
- To provide landlord support for the centralized Oak Ridge Operations Office and the Oak Ridge Reservation activities.

Program Objectives

- To correct Environment, Safety and Health (ES&H) inadequacies.
- To reduce risk of operational interruptions due to failed support systems.
- To provide cost effective operations and reduce maintenance costs.
- To provide quality space for multiprogram research and support activities.
- To preserve the government investment in the physical plant of the multiprogram laboratories.
- To promote performance-based infrastructure management.
- To support local communities via Payments in Lieu of Taxes (PILT).
- To provide landlord support for the Oak Ridge Reservation and for the Oak Ridge Operations Office.

Significant Accomplishments and Program Shifts

- Progress in Line Item Projects – Two projects were completed in FY 2000: the Building Electrical Services Upgrade – Phase I at ANL-E and the Electrical Services Rehabilitation – Phase IV at LBNL. Three projects are scheduled for completion in FY 2001: the Central Supply Facility at ANL-E; the Electrical Systems Modifications – Phase I at BNL; and the Electrical Systems Upgrade - Phase III at ANL-E. Two projects are scheduled for completion in FY 2002: Building 77 - Rehabilitation of Building Structure and Systems at LBNL and the Sanitary Systems Modifications – Phase III at BNL.
- The scope of the Building 77-Rehabilitation of Building Structure and Systems project at LBNL was reduced to eliminate the mechanical, electrical and architectural work from the project. This leaves only the structural work which will arrest the differential settling and reinforce the lateral force resisting system of the building. This reduction was necessitated by the original bids for construction being significantly higher than expected due to a tight labor market, work difficulty and location, and operational commitments in the facility that limited the work site availability. This rescoping of the project has added seven months to the project schedule.
- The direct funding for the American Museum for Science and Energy under the Oak Ridge Landlord subprogram ended in FY 2000. Museum operation was transferred to the Oak Ridge National Laboratory where alternative funding mechanisms are being developed, including support by private or industrial partners, and, possibly, an admission fee for adults.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Multiprogram Energy Laboratories-Facilities Support					
Multiprogram Energy Laboratories-Facilities Support	21,255	23,219	-404	22,815	22,816
Oak Ridge Landlord	8,302	10,711	-3,352	7,359	7,359
Total, Multiprogram Energy Laboratories-Facilities Support	29,557[a]	33,930	-3,756	30,174	30,175
General Reduction	0	-315	315	0	0
General Reduction for Safeguards and Security	0	-3,373	3,373	0	0
Omnibus Rescission	0	-68	68	0	0
Total, Multiprogram Energy Laboratories – Facilities Support	29,557 [a]	30,174	0	30,174	30,175

Public Law Authorization:
Public Law 95-91, “Department of Energy Organization Act”
Public Law 103-62, “Government Performance and Results Act of 1993”

[a] Excludes $3,498,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

Funding by Site

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Chicago Operations Office					
Argonne National Laboratory	4,980	6,611	2,833	-3,778	-57.1%
Brookhaven National Laboratory	6,881	6,444	6,063	-381	-5.9%
Chicago Operations Office	1,890	1,020	1,020	0	0.0%
Total, Chicago Operations Office..................	13,751	14,075	9,916	-4,159	-29.5%
Oakland Operations Office					
Lawrence Berkeley National Laboratory....	6,133	2,113	4,400	+2,287	+108.2%
Oak Ridge Operations Office					
Oak Ridge National Laboratory	1,101	6,627	7,620	+993	+15.0%
Oak Ridge Operations Office..................	8,302	7,359	7,359	0	0.0%
Total, Oak Ridge Operations Office	9,403	13,986	14,979	+993	+7.1%
Richland Operations Office...........................					
Pacific Northwest National Laboratory......	0	0	880	+880	+100.0%
Washington Headquarters	270	0	0	0	--
Total, Multiprogram Energy Laboratories - Facilities Support	29,557 [a]	30,174	30,715	+1	--

[a] Excludes $3,498,000 in FY 2000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

Site Description

Argonne National Laboratory - East

Argonne National Laboratory - East (ANL-E) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. The laboratory consists of 122 facilities, 4.6 million gross square feet of space, with the average age of the facilities being 31 years. Approximately 44 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes funding the following projects:

- MEL-001-09 Fire Safety Improvements - Phase IV (TEC $8,381,000) This project will bring 30 major facilities into compliance with the Life Safety Code and the National Fire Alarm Code.

- MEL-001-17 Mechanical and Control Systems Upgrade – Phase I (TEC $9,000,000) This proposed new start for FY 2002 will upgrade or replace 30-40 year old, deteriorated mechanical system components in various facilities. These will include HVAC, drainage, steam supply, and condensate return systems. This project will optimize capacity, enhance system reliability and performance, improve safety, and reduce maintenance costs. These systems are no longer adequate, reliable, or efficient, and do not meet current ES&H standards (e.g., failure of a laboratory exhaust system could lead to release of radioactive material).

The program also provides funding through the Chicago Operations Office for Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation.

Brookhaven National Laboratory

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The laboratory consists of 349 facilities, 4.1 million gross square feet of space, with the average age of the facilities being 39 years. Approximately 35 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes funding the following projects:

- MEL-001-13 Groundwater and Surface Water Protection Upgrades (TEC $6,050,000) This on-going project will address a backlog of ground and surface water protection projects which are commitments to regulators. These include: proper closure of inactive supply and injection wells; runoff control for the surplus material storage yard; containment and runoff control for the radioactive material storage yard; replacement of 12 hydraulic elevator cylinders; removal of 22 underground fuel oil tanks; and replacement of radioactive waste tanks with secondarily contained tanks.

- MEL-001-16 Electrical Systems Modifications, II (TEC $6,770,000) This ongoing project is the second phase of the modernization and refurbishment of the laboratory's deteriorating 50 year-old electrical infrastructure. The project includes: installation of two new 13.8 kV feeders to provide alternate sources to existing, aged feeders; installation of additional underground ductbanks to support a new 13.8 kV feeder; replacement of 2.4 kV switchgear to increase system reliability and safety; reconditioning of 50 480-volt circuit breakers including replacing obsolete trip units with modern, solid-state trip devices; and the retrofit of 10 13.8 kV air breakers with new vacuum technology.

The program also provides funding through the Chicago Operations Office for Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The laboratory is on a 200 acre site adjacent to the Berkeley campus branch of the University of California. The laboratory consists of 118 facilities, 1.6 million gross square feet of space, with the average age of the facilities being 34 years. Approximately 15 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes funding the following project:

- MEL-001-12 Site-wide Water Distribution System Upgrade (TEC $8,300,000) This ongoing project rehabilitates the Lab's High Pressure Water (HPW) System to include: replacement of all 1.4 km of cast iron pipe with ductile iron pipe; installing cathodic protection; replacing and adding pressure reducing stations to prevent excessive system pressure at lower lab elevations; adding an emergency fire water tank to serve the East Canyon; and providing the two current emergency fire water tanks with new liners and seismic upgrades.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The laboratory consists of 466 facilities, 3.4 million gross square feet of space, with the average age of the facilities being 37 years. Approximately 20 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes to fund the following projects:

- MEL-001-14 Fire Protection System Upgrade (TEC $5,920,000) This ongoing project replaces deteriorated, obsolete systems with more reliable fire alarm and suppression capabilities; replaces the single 16-inch water main in the east central section of ORNL with a looped system; and extends coverage of automatic alarm and sprinkler systems to areas not previously served. Upgrading the fire alarm receiving equipment at the site fire department headquarters ensures its reliability, modernizes its technology, and meets the demands of an expanded fire alarm system network.

- MEL-001-15 Laboratory Facilities HVAC Upgrade (TEC $7,100,000) This ongoing project provides improvements to aging HVAC systems (average age 38 years) located in the 13 buildings which comprise ORNL's central research complex and make additions and improvements to the chilled water distribution system. This includes: redesign of the cooling water distribution system to reduce the number of pumps required and installing more efficient pumps, thereby reducing operations and maintenance costs; installation of an 800 ft., 8-inch-diameter pipe, chill water cross-tie to Buildings 4501/4505 from the underground tie-line between Buildings 4500N/4509 to address low capacity problems in 4501/4505; installation of a 500 ft. 4-inch-diameter pipe to feed new chilled water coils in the east wing of Building 3500; upgrade of the existing 50 year-old air handler with new dampers, filters, steam coils, and controls; and replacement of constant volume, obsolete air handlers in various buildings with variable air volume (VAV) improvements to more efficiently control temperature.

- MEL-001-25 Research Support Center (TEC $16,100,000) This proposed new start for FY 2002 will construct a 50,000 sq. ft. facility to house the core support service facilities and serve as the cornerstone and focal point of the East Research Campus envisioned in the ORNL Facility Revitalization Project. This building will include an auditorium and conference center, cafeteria, visitor reception and control area, and support offices for approximately 50 occupants. It will facilitate consolidation of functions which are presently scattered throughout the Laboratory complex in facilities that are old (30-50 years), undersized, poorly located, or scheduled for surplus. The facility will serve as a modern center for meeting, collaborating, and exchanging scientific ideas for ORNL staff and the nearly 30,000 visitors, guests, and collaborators that use ORNL facilities each year. The new cafeteria will replace the existing cafeteria, which was constructed in 1953. The existing cafeteria is poorly located to serve the current staff and is adjacent to the original production area of the lab now undergoing decontamination. The estimated simple payback is seven years.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on a 960 acre site on the south end of the Hanford Reservation near Richland, Washington. The laboratory consists of 40 facilities, 0.9 million gross square feet of space, with the average age of the facilities being 29 years. Approximately 36 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program proposes funding the following project:

- MEL-001-18 Laboratory Systems Upgrades (TEC $9,000,000) This proposed new start for FY 2002 will upgrade or replace 20-50 year old mechanical system components in eight high occupancy facilities at PNNL. This project will upgrade these obsolete systems with more efficient, better performing systems to enhance the quality of science while reducing maintenance and energy costs. This upgrade will include: replacement of HVAC supply and exhaust fans; replacement, rehabilitation or modification of numerous chemical exhaust fume hoods; installation of computerized, remote, digital controls on various systems to improve operations; and replacement of an emergency power generator.

Chicago Operations Office

The Chicago Operations Office processes the Payments in Lieu of Taxes made to the local taxing authorities at Brookhaven National Laboratory and Argonne National Laboratory-East.

Oak Ridge Operations Office

The Oak Ridge Landlord program provides for centralized Oak Ridge Operations Office (ORO) infrastructure requirements and general operating costs for activities on the Oak Ridge Reservation outside plant fences and activities to maintain a viable operations office, including maintenance of roads and grounds and other infrastructure, operation of the Emergency Management Program Office, Payments In Lieu of Taxes, and support for the Oak Ridge Financial Service Center as well as other technical needs related to landlord activities.

Multiprogram Energy Laboratories - Facilities Support

Mission Supporting Goals and Objectives

This subprogram supports the program's goal to ensure that support facilities at the five Office of Science (SC) multiprogram national laboratories can meet the Department's research needs primarily by refurbishing or replacing deteriorated, outmoded, unsafe, and inefficient general purpose infrastructure. General purpose facilities are general use, service and support facilities such as administrative space, cafeterias, general office/laboratory space, utility systems, sanitary sewers, roads, etc.

The subprogram strives to improve the condition of laboratory buildings (i.e., increasing the percentage of buildings rated adequate). **Performance will be measured** by the increase in the percentage of facilities rated adequate over time. The percentage of space rated adequate increased from 26% in FY 1998 to 30% in FY 2000.

Capital investment requirements are identified in laboratory Strategic Facilities Plans that address infrastructure needs through the year 2011 to adequately support expected programmatic activities. These plans (currently under SC review) assume the full modernization/revitalization of the general purpose infrastructure of the multiprogram labs will be completed over this period. The projected investments total is ~$1,000,000,000. Of this amount, 85% is to rehabilitate or replace buildings; 9% is for utility projects; and 6% for ES&H and other projects.

The large backlog of building related projects reflects the fact that the condition of only 50% of the laboratory space is considered fully adequate, while the remaining 50% needs rehabilitation or replacement/demolition. Often, even adequate space is not functional for modern research purposes (e.g., a well maintained 1940 vintage wooden barracks is not particularly useful when modern lab/office space is needed). The large percentage of inadequate space is due to:

- the age of the facilities (over 69% of the buildings are 30 years old or older and, 43% are 40 years old or older)
- changing research needs that require different kinds of space (e.g., more office space and light laboratory space than hot cells)
- obsolescence of existing systems and components
- changing technology (e.g., digital controls)
- changing environmental, safety and health regulations, and
- inadequate capital investment in the past

The backlog of utilities and ES&H projects is much lower ($150,000,000 or 15% of the total backlog) due to investments by the MEL-FS program over the last 20 years. Utilities and ES&H projects consistently scored highest and limited funding did not allow many building needs to be addressed.

In any given budget year, all candidate projects for funding are first ranked using the Life Cycle Asset Management (LCAM) Cost-Risk-Impact Matrix that takes into account risk, impacts, and mission need. The projects that have ES&H as the principal driver are further prioritized using the Risk Prioritization Model from the DOE ES&H and Infrastructure Management Plan process. Based on these rankings, the subprogram funds the highest priority projects that reduce risk, ensure continuity of operations, avoid or reduce costs, and increase productivity. **Performance will be measured by** the percentage of projects that rank among the highest priority projects and have a Capital Asset Management Process (CAMP) ranking score of greater than 50. All FY 2000-FY 2002 funded projects were evaluated by an integrated infrastructure management team as the highest priority projects and each has a CAMP score greater than 60.

The subprogram ensures that the funded projects are managed effectively and completed within the established cost, scope and schedule baselines. **Performance will be measured by** the number of projects completed within the approved baselines for cost (at or below the appropriated TEC), scope (within 10%), and schedule (within six months). Both projects scheduled for completion in FY 2000 were completed within the approved baselines for cost, scope, and schedule.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Purpose Facilities	14,495	8,816	5,380	-3,436	-39.0%
Environment, Safety and Health	4,600	12,979	16,416	+3,437	+26.5%
Infrastructure Support	2,160	1,020	1,020	0	--
Total, Multiprogram Energy Laboratories - Facilities Support	21,255	22,815	22,816	+1	--

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
General Purpose Facilities	**14,495**	**8,816**	**5,380**

Provides funding to support the initiation of two new subprojects in FY 2002 as well as the continuation of one FY 2001 subproject under the Multiprogram Energy Laboratories Infrastructure Project (MEL-001). The FY 2002 funding is for design activities for the following projects: Laboratory Systems Upgrade at PNNL ($880,000); and Research Support Center at ORNL ($1,500,000). The FY 2001 subproject is the Laboratory Facilities HVAC Upgrade at ORNL ($3,000,000).

Environment, Safety and Health	**4,600**	**12,979**	**16,416**

Provides funding to support the initiation of one new ES&H subproject in FY 2002, as well as the continuation of four FY 2001 subprojects under the Multiprogram Energy Laboratories Infrastructure

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

Project (MEL-001). The FY 2002 funding for the new start is for design activities for the Mechanical and Control Systems Upgrade – Phase I at ANL-E ($803,000). The FY 2001 subprojects are: Groundwater and Surface Water Protection Upgrades at BNL ($2,763,000); Fire Protection System Upgrade at ORNL ($ 3,120,000); Site-wide Water Distribution System Upgrade at LBNL ($4,400,000); and Electrical Systems Modifications - Phase II at BNL ($3,300,000). The request also supports the completion of Fire Safety Improvements - Phase IV at ANL-E ($2,030,000).

	FY 2000	FY 2001	FY 2002
Infrastructure Support	**2,160**	**1,020**	**1,020**
■ **Payment in Lieu of Taxes (PILT)**	2,160	1,020	1,020

Continue meeting Payments in Lieu of Taxes (PILT) assistance requirements for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory-East. **Performance will be measured** by the Department funding the PILT payments at the levels negotiated with the local governments. The PILT payments equaled the negotiated levels in FY 2000.

	FY 2000	FY 2001	FY 2002
Total, Multiprogram Energy Laboratories – Facilities Support	**21,255**	**22,815**	**22,816**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Multiprogram Energy Laboratories – Facilities Support	
■ Continue at FY 2001 level.	+1
Total Funding Change, Multiprogram Energy Laboratories - Facilities Support	+1

Oak Ridge Landlord

Mission Supporting Goals and Objectives

This subprogram supports landlord responsibilities for the centralized Oak Ridge Operations Office (ORO) including infrastructure of the Oak Ridge Reservation (the 24,000 acres of the Reservation outside of the Y-12 plant, ORNL, and the East Tennessee Technology Park), and DOE facilities in the town of Oak Ridge. This includes roads and grounds and other infrastructure maintenance, ES&H support and improvements, support for the emergency management operations, support of the Oak Ridge Financial Service Center, PILT for Oak Ridge communities, and other technical needs related to landlord requirements. These activities maintain continuity of operations at the Oak Ridge Reservation and the ORO and minimize interruptions due to infrastructure or emergency management and other systems failures. **Performance will be measured** by the number of significant ORO interruptions which can be directly attributed to infrastructure failures. In FY 2000 there were no significant interruptions due to infrastructure failures.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Oak Ridge Landlord	8,302	7,359	7,359	0	--

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
■ **Roads, Grounds and Other Infrastructure and ES&H Support and Improvements**	2,180	2,200	2,200
■ **Emergency Management Program Office**	1,223	664	664

Provides for the operation of the Oak Ridge Emergency Operations Center and the Communications and Operations Center.

	FY 2000	FY 2001	FY 2002
■ **Payments in Lieu of Taxes (PILT)**	1,916	1,900	1,900

Payments in Lieu of Taxes (PILT) to the City of Oak Ridge, and Anderson and Roane Counties.

	FY 2000	FY 2001	FY 2002
■ **American Museum of Science and Energy**	400	0	0

FY 2000 is the last year direct support for the museum is provided. Museum operation was transferred to ORNL where alternative funding mechanisms are being developed, including support by private or industrial partners, and, possibly, an admission fee for adults.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
■ **Oak Ridge Financial Service Center**.................................	1,635	1,700	1,700
Provides computer and systems support to the Center which serves other DOE field offices as well as Oak Ridge.			
■ **Technical Support**..	948	895	895
Includes recurring activities such as computer and systems support for Directives and Training activities and one-time activities such as the identification, packaging, and shipment of documents relating to Human Radiation Experimentation to the National Archives for permanent storage, and support for legacy legal cases.			
Total, Oak Ridge Landlord..	**8,302**	**7,359**	**7,359**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)

Oak Ridge Landlord

- No changes from FY 2001 to FY 2002.

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects	0	200	0	-200	-100.0%
Capital Equipment	100	315	315	0	--
Total, Capital Operating Expenses	100	515	315	-200	-38.8%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2000	FY 2001	FY 2002	Unapprop. Balance
Project – 02-SC-001 Multiprogram Energy Laboratories Infrastructure Project FY 2002 PED Datasheet	N/A	N/A	0	0	3,183	0
Project - MEL-001 Multiprogram Energy Laboratories Infrastructure Project FY 2002 Construction Datasheet	N/A	N/A	18,351	21,795	18,613	13,029
Total, MELFS Construction	N/A	N/A	19,095 [a]	21,795	21,796	13,029

[a] Total MELFS construction, including projects fiscally completed prior to FY 2001. Includes $744 to complete funding for project 94-E-363, Roofing Improvements (ORNL).

MEL-001 - Multiprogram Energy Laboratories, Infrastructure Project, Various Locations

(Changes from FY 2001 Congressional Budget Request are denoted with a vertical line in the left margin.)

Significant Changes

The scope on the Building 77-Rehabilitation of Building Structure and Systems project was reduced to eliminate the mechanical, electrical and architectural work from the project. This leaves only the structural work which will arrest the differential settling and reinforce the lateral force resisting system of the building. This reduction was necessitated by the original bids for construction being significantly higher than expected due to a tight labor market, work difficulty and location, and operational commitments in the facility that limited the work site availability. The rescoping of the project has added seven months to the project schedule.

1. Construction Schedule History

Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		

N/A -- See subproject details

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Construction			
Prior Years	10,383	10,383	3,916
FY 2000	18,351	18,351	17,789
FY 2001	21,795	21,795	22,303
FY 2002	18,613	18,613	17,631
FY 2003	13,029	13,029	19,477
FY 2004	0	0	1,055

3. Project Description, Justification and Scope

This project funds two types of subprojects:

- Projects that renovate or replace inefficient and unreliable general purpose facilities (GPF) including general use, service and support facilities such as administrative space, cafeterias, utility systems, and roads; and
- Projects to correct ES&H deficiencies including deteriorated steam lines, environmental insult, fire safety improvements, sanitary system upgrades and electrical system replacements.

General Purpose Facility Projects:

a. Subproject 04 - Electrical Systems Modifications, Phase I (BNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
5,730	849	3,881	1,000	0	0	2Q 2000 - 4Q 2001

This project is the first phase of a planned modernization and refurbishment of the Laboratory's electrical infrastructure. The project provides for the replacement of 30 to 50 year old deteriorating underground electrical cables, the addition of underground ductbanks to replace damaged portions and support new cabling, the installation of a new 13.8 kV - 2.4 kV step-down transformer substation to address capacity and operational problems, and the retrofitting/reconditioning of switchgear power circuit breakers.

b. Subproject 05 - Bldg. 77 - Rehabilitation of Building Structure and Systems (LBNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
8,000	754	6,133	1,113	0	0	3Q 2000 - 2Q 2002

This project will rehabilitate Building 77's structural system to restore lateral force resistance and arrest differential foundation settlement. These upgrades will restore this 33 year-old, 68,000 sq.ft. building to acceptable seismic performance and prevent loss at this facility due to structure failures.

c. Subproject 06 - Central Supply Facility (ANL-E)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates

5,900	1,860	3,380	660	0	0	3Q 2000 - 4Q 2001

This project includes a 22,000 sq.ft. addition to the Transportation and Grounds Facility (Bldg. 46) along with remodeling of 3,500 sq.ft. of space in the existing Transportation and Grounds Facility. The project will result in economies and efficiencies by providing a highly efficient and cost-effective consolidated facility to meet the missions of the Materials Group and the Property Group of ANL-East and will eliminate the need for 89,630 square feet of substandard (50 year-old) space in six buildings which will be demolished (Bldgs. 4, 5, 6, 26, 27, and 28). The Materials Group receives, sorts, stores, retrieves, and distributes the majority of all materials and supplies for the Laboratory. The Property Group tags, controls, stores, and distributes excess property and precious metals for the Laboratory. This facility will contain truck docks; receiving and distribution areas; inventory control; general material storage; support and office areas; property storage; and exterior hazardous storage. This project will also eliminate 7,000 linear feet of steam supply and return lines.

d. Subproject 08 - Electrical Systems Upgrade (ORNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
5,900	0	357	5,543	0	0	3Q 2001 - 2Q 2003

This project will replace electrical distribution feeders and upgrade transformers and switchgear feeding research facilities and primary utility support facilities throughout the Oak Ridge National Laboratory (ORNL) complex. It will also provide advanced protective relaying and metering capabilities at major substations. The project is part of a phased infrastructure upgrade to restore the electrical distribution systems serving the ORNL. The purpose of the upgrade is to maintain a reliable source of electrical power appropriate for servicing scientific research facilities. Without the proposed upgrade, the potential for electrical faults and outages will increase as the distribution system ages, with attendant increased risk of equipment damage and the potential inability to meet laboratory programmatic goals due to downtime of critical facilities. These facilities include the central research facilities, supercomputing facility, Robotics and Process Systems facility, the central chilled water plant, and the steam plant. Also, maintenance costs involved in continued operation of the existing deteriorated system will increase as the system ages.

e. Subproject 15 – Laboratory Facilities HVAC Upgrade (ORNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
7,100	0	0	500	3,000	3,600	3Q 2002 – 2Q 2004

This project will provide improvements to aging HVAC systems (average age 38 years) located in the thirteen (13) buildings which comprise Oak Ridge National Laboratory's (ORNL's) central research complex and additions and improvements to the chiller water distribution system. This includes:
redesign of the cooling water distribution system to reduce the number of pumps required and installing more

efficient pumps, thereby reducing operations and maintenance costs; installation of an 800 ft., 8-inch-diameter pipe, chill water cross-tie to Bldgs. 4501/4505 from the underground tie-line between Bldgs. 4500N/4509 to address low capacity problems in 4501/4505; installation of a 500 ft. 4-inch-diameter pipe to feed new chilled water coils in the east wing of Bldg. 3500; upgrade of the existing 50 year-old air handler with new dampers, filters, steam coils, and controls; and replacement of constant volume, obsolete air handlers in various buildings with variable air volume (VAV) improvements to more efficiently control temperature.

ES&H Projects:

a. Subproject 03 - Electrical Systems Upgrade - Phase III, (ANL-E)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
7,620	6,420	1,200	0	0	0	2Q 1999 - 1Q 2001

The project provides for the upgrade of the main electrical substation at Facility 543 and Facility 549A.

The work consists of the following items: install a new 138 kV overhead steel pole transmission line and upgrade the existing transmission line, relocate an existing transformer, upgrade existing transformers, replace existing 13.2 kV outdoor switchgear, and replace existing oil circuit breaker.

The intended project will accomplish several objectives related to system reliability, personnel safety, environmental hazards, risk reduction and system expansion.

b. Subproject 07 - Sanitary System Modifications - Phase III, (BNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
6,500	500	3,000	3,000	0	0	1Q 2000 - 2Q 2002

The BNL Sanitary System consists of over 20 miles of collection piping that collects sanitary waste from nearly all the BNL facilities. The collection piping transports the waste via gravity piping and lift stations to a sewage treatment plant (STP). This project is the third phase of the upgrade of the Laboratory sanitary waste system. In the first two phases, major operations of the STP were upgraded and approximately 14,000 feet of trunk sewer lines were replaced, repaired, or lined. Phase III will continue this upgrade and will replace or rehabilitate approximately 9,900 feet of existing deteriorated (8 to 20 inch) sewer piping, connect five facilities to the sanitary system by installing 7,500 feet of new sewer pipe, and two new lift stations. This will eliminate non-compliant leaching fields and cess pools, reduce non-contact cooling water flow into the sewage system by 72 million gallons per year by: diverting flow to the storm system; converting water heat exchangers to air cooled condensers; and replacing water cooled equipment in 15 buildings. The STP anaerobic sludge digester will be replaced with an aerobic sludge digester to eliminate high maintenance activity and improve performance.

c. Subproject 09 - Fire Safety Improvements, Phase IV, (ANL-E)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
8,381	0	400	5,951	2,030	0	3Q 2001 - 2Q 2003

This project will complete the effort of correcting known deficiencies with respect to fire detection and alarm systems; life safety and OSHA related sprinkler systems; and critical means of egress in twenty-eight (28) buildings at the Argonne National Laboratory-East (ANL-E) site. Correction of these deficiencies is required to comply with DOE Order 420.1, OSHA 1910,164, and OSHA Subpart C. These deficiencies, if uncorrected, could result in unmitigated risks of injury to personnel and/or damage to DOE property in case of fire.

d. Subproject 12 - Site-wide Water Distribution System Upgrade, (LBNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
8,300	0	0	1,000	4,400	2,900	2Q 2002 – 1Q 2004

This project will rehabilitate the Laboratory's High Pressure Water (HPW) System that supplies over 100 facilities at LBNL. The HPW System provides domestic water, fire water, treated water, cooling tower water and low conductivity water. It consists of 9.6 km of pipe (1.4 km of cast iron pipe, 6.3 km of ductile iron pipe, and 1.9 km of cement lined coated steel pipe), associated valves, pumps, fittings etc. and two 200,000 gallon emergency fire water tanks. This project will: replace all cast iron pipe, which is in imminent danger of failing, with ductile iron pipe; electrically isolate pipe and provide cathodic protection; replace leaking valves and add pressure reducing stations to prevent excessive system pressure at lower lab elevations; add an emergency fire water tank to serve the East Canyon; and provide the two current emergency fire water tanks with new liners and seismic upgrades.

e. Subproject 13 - Groundwater and Surface Water Protection Upgrades, (BNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
6,050	0	0	1,889	2,763	1,398	2Q 2002 - 1Q 2004

This project will implement a backlog of ground and surface water protection projects that are commitments to regulators. These include: proper closure of inactive supply and injection wells; runoff control for the surplus material storage yard; containment and runoff control for the radioactive material storage yard; replacement of 12 hydraulic elevator cylinders; removal of 22 underground fuel oil tanks; and other Suffolk County DHS Article 12 upgrades.

f. Subproject 14 - Fire Protection System Upgrade, (ORNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
5,920	0	0	584	3,120	2,216	3Q 2002 - 4Q 2004

This project will upgrade the 36 year-old fire protection system with improved, more reliable fire alarm and suppression capabilities by: replacing deteriorated, obsolete systems; replacing the single 16-inch water main in the east central section of ORNL with a looped system (7,000 lf of 16 inch pipe); and by extending coverage of automatic alarm systems and sprinkler systems to areas not previously served. New fire alarm equipment will provide emergency responders with greatly improved annunciation of the causes and locations of alarms and will provide code compliant occupant notification evacuation alarms for enhanced life safety. It will also include timesaving, automatic diagnostic capabilities that will reduce maintenance costs. The new occupant notification systems will comply with the Americans with Disabilities Act. The fire alarm receiving equipment at the site fire department headquarters will be upgraded to ensure its reliability, modernize its technology, and meet the demands of an expanded fire alarm system network.

g. Subproject 16 – Electrical Systems Modifications II, (BNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
6,770	0	0	555	3,300	2,915	2Q 2002 – 1Q 2004

This project is the second phase of the modernization and refurbishment of the Laboratory's deteriorating 50 year-old electrical infrastructure. The project includes: installation of two new 13.8 kV feeders to provide alternate sources to existing, aged feeders; installation of additional underground ductbanks to support a new 13.8 kV feeder; replacement of 2.4 kV switchgear to increase system reliability/safety; reconditioning of 50 480-volt circuit breakers including replacing obsolete trip units with modern, solid-state trip devices; and the retrofit of 10 13.8 kV air breakers with new vacuum technology.

4. Details of Cost Estimate

N/A

5. Method of Performance

To the extent feasible, construction and procurement will be accomplished by fixed-price contracts awarded on the basis of competitive bids.

6. Schedule of Project Funding

N/A

7. Related Annual Funding Requirements

N/A

8. Design and Construction of Federal Facilities

All DOE facilities are designed and constructed in accordance with applicable Public Laws, Executive Orders, OMB Circulars, Federal Property Management Regulations, and DOE Orders. The total estimated cost of the project includes the cost of measures necessary to assure compliance with Executive Order 12088, "Federal Compliance with Pollution Control Standards;" section 19 of the Occupational Safety and Health Act of 1970, the provisions of Executive Order 12196, and the related Safety and Health provisions for Federal Employees (CFR Title 29, Chapter XVII, Part 1960); and the Architectural Barriers Act, Public Law 90-480, and implementing instructions in 41 CFR 101-19.6. The project will be located in an area not subject to flooding determined in accordance with Executive Order 11988. DOE has reviewed the GSA inventory of Federal Scientific laboratories and found insufficient space available, as reported by the GSA inventory.

02-SC-001 - Multiprogram Energy Laboratories, Project Engineering Design (PED), Various Locations

1. Construction Schedule History

Fiscal Quarter				Total Estimated Cost ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete	

N/A – See Subproject details

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	3,183	3,183	2,385
2003	0	0	798

3. Project Description, Justification and Scope

This project funds PED for two types of subprojects:

- Projects that renovate or replace inefficient and unreliable general purpose facilities (GPF) including general use, service and support facilities such as administrative space, cafeterias, utility systems, and roads; and
- Projects to correct Environment, Safety and Health (ES&H) deficiencies including deteriorated steam lines, environmental insult, fire safety improvements, sanitary system upgrades and electrical system replacements.

This PED data sheet requests design funding for three FY 2002 new starts. The following three new projects that will be started in FY 2002 are: Mechanical and Control Systems Upgrade – Phase I at Argonne National Laboratory – East; Laboratory Systems Upgrades at Pacific Northwest National Laboratory; and Research Support Center at Oak Ridge National Laboratory.

FY 2002 Proposed Design Projects

General Purpose Facility Projects:

02 -01: MEL-001-018 – Laboratory Systems Upgrades (PNNL)

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2002	3Q 2002	2Q 2003	N/A	880	9,000

Fiscal Year	Appropriations	Obligations	Costs
2002	880	880	660
2003	0	0	220

This design project will provide design to upgrade or replace 20-50 year old mechanical system components in eight high occupancy facilities at PNNL. This project will upgrade these obsolete systems with more efficient, better performing systems to enhance the quality of science while reducing maintenance and energy costs. This upgrade will include: replacement of HVAC supply and exhaust fans; replacement, rehabilitation or modification of numerous chemical exhaust fume hoods; installation of computerized, remote, digital controls on various systems to improve operations; and replacement of an emergency power generator.

02 -03: MEL-001-025 – Research Support Center (ORNL)

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2002	3Q 2002	2Q 2004	N/A	1,500	16,100

Fiscal Year	Appropriations	Obligations	Costs
2002	1,500	1,500	1,125
2003	0	0	375

This design project will construct a 50,000 sq. ft. facility to house the core support service facilities and serve as the cornerstone and focal point of the East Research Campus envisioned in the ORNL Facility Revitalization Project. This building will include an auditorium and conference center, cafeteria, visitor reception and control area, and support offices for approximately 50 occupants. It will facilitate consolidation of functions which are presently scattered throughout the Laboratory complex in facilities that

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

are old (30-50 years), undersized, poorly located, or scheduled for surplus. The facility will serve as a modern center for meeting, collaborating, and exchanging scientific ideas for ORNL staff and the nearly 30,000 visitors, guests, and collaborators that use ORNL facilities each year. The new cafeteria will replace the existing cafeteria which was constructed in 1953. The existing cafeteria is poorly located to serve the current staff and is adjacent to the original production area of the lab now undergoing decontamination. The estimated simple payback is seven years.

ES&H Projects:

02-08: MEL-001-017 – Mechanical and Control Systems Upgrade – Phase I (ANL-E)

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2002	3Q 2002	2Q 2003	NA	803	9,000

Fiscal Year	Appropriations	Obligations	Costs
2002	803	803	600
2003	0	0	203

This design project will provide design to upgrade and replace 30-40 year old mechanical system components in various facilities. It will optimize capacity, enhance system reliability and performance, improve safety, and reduce maintenance and repair costs of primary building mechanical equipment and control systems. The mechanical systems designated for replacement are no longer adequate, reliable, or efficient, and do not meet current ES&H standards (i.e. failure of laboratory exhaust systems could lead to the release of radioactive material). Specifically, this project will: upgrade HVAC systems in Bldgs. 221 and 362, including heating and cooling coils, fans, filter systems, ductwork, controls, and variable frequency drive fans; upgrade lab exhaust systems in Bldgs. 202 and 306, including new fans, ductwork, and controls; upgrade corroded drainage systems in Bldgs. 200, 205 and 350; and upgrade steam and condensate return systems in 12 facilities in the 360 area. This will include high and low pressure steam supply piping and associated pressure reducing stations, valves, and accessories; and replacing condensate pumping systems including piping, valves and system controls.

4. Details of Cost Estimate

N/A

5. Method of Performance

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

Design services will be obtained through competitive and/or negotiated contracts. M&O contractor staff may be utilized in areas involving security, production, proliferation, etc. concerns.

6. Schedule of Project Funding

N/A

Fusion Energy Sciences

Program Mission

By providing support for the Fusion Energy Sciences (FES) program, DOE serves a unique role as the only source of funding for fusion science and high temperature plasma physics in the United States, and as a major source of funds for general plasma science research. The mission of the FES program, a multi-purpose, scientific research effort, is

> *"to advance plasma science, fusion science, and fusion technology--the knowledge base needed for an economically and environmentally attractive fusion energy source."*

The Policy Goals associated with this mission are:

- Advance plasma science and technology in pursuit of national science and technology goals.
- Develop fusion science, technology, and plasma confinement innovations as the central theme of the domestic program.
- Pursue fusion energy science and technology as a partner in the international effort.

This mission statement and its associated Policy Goals have been developed with extensive stakeholder input, and they have been endorsed by the Fusion Energy Sciences Advisory Committee (FESAC) and the Secretary of Energy Advisory Board (SEAB).

Plasma science is the study of the ionized matter that makes up 99 percent of the observable universe. Plasmas can be seen in many different venues, ranging from neon lights to stars. Plasma science includes not only plasma physics but also other physical phenomena in ionized matter, such as atomic, molecular, radiation-transport, and excitation and ionization processes. These phenomena can play significant roles in plasmas and in the interaction of plasmas with particles that result from the fusion process, electro-magnetic waves used to heat the plasma, and the material walls surrounding the plasma. Plasma science and technology contributes not only to fusion research, but also to national security and many other fields of science and technology such as astrophysics and industrial processing.

Fusion science deals primarily with describing the fundamental processes taking place in plasmas where the temperature and density approach those needed to allow the nuclei of two light elements, like hydrogen, to join together, or fuse. When these nuclei fuse, a large amount of energy is released. While fusion science shares many issues with plasma science, research is organized around the two leading methods of confining the fusion plasma—magnetic, wherein strong magnetic fields constrain the charged plasma particles, and inertial, wherein laser or particle beams compress the plasma for short pulses. For magnetic fusion, the scientific issues include:

1. the transport of plasma heat from the core outwards to the plasma edge and to the material walls as a result of electromagnetic turbulence in the plasma (chaos, turbulence, and transport),
2. the stability of the magnetic configuration and its variation in time as the plasma pressure, density, turbulence level, and population of high energy fusion products changes (stability, reconnection, and dynamo),
3. the role of the colder plasma at the plasma edge and its interaction with both material walls and the hot plasma core (sheaths and boundary layers), and

4. the interaction of electrons and ions in the plasma with high-power electromagnetic waves injected into the plasma for plasma heating, current drive and control (wave-particle interaction).

For inertial fusion, the scientific issues include:

1. high energy density physics, such as laser-plasma and beam-plasma interactions, and
2. the behavior of non-neutral plasmas (such as beams of electrons or ions).

Progress in all of these issues is likely to be required for ultimate success in achieving a practical fusion energy source.

Enabling research and development activities, such as support for enhancing the operational capabilities of experimental facilities, and materials science research are closely associated with fusion science.

Fusion energy science and technology refers to the science of a self-heated, or burning plasma, and the specific set of activities that need to be explored to make fusion a practical energy source in the long term. The program is pursuing these specific activities at a low level of funding; any major effort in this area will only be undertaken in collaboration with international partners.

Both the President's Committee of Advisors on Science and Technology and SEAB have recognized the potential of fusion and have recommended that fusion be a key component of the nation's long-term energy strategy. The National Research Council (NRC) has endorsed the dual nature of the FES program as a science program and as a long-term energy program. NRC has stated that fusion research has made remarkable strides over the years, and the quality of the science produced by the DOE funded fusion program is easily on a par with other leading areas of contemporary physical science. In recent years, as the program has focused on the key science issues described above, we have made dramatic progress in understanding the extraordinarily complex medium called plasma. For the first time, we are able to predict detailed behavior and control some of the micro-turbulence that has limited our ability to confine hot plasma in magnetic fields.

Program Goals

During 1998-1999, FESAC conducted a major review of the fusion program that culminated in the report "Priorities and Balance within the Fusion Energy Sciences Program," dated September 1999. A hallmark of this report is its attempt to deal even handedly with magnetic fusion science and inertial fusion science. In December 2000, FESAC reaffirmed that the priorities, balance, and strategic vision laid out in its 1999 report remain valid. Based on that report, the programmatic goals for the Magnetic Fusion Energy (MFE) and the Inertial Fusion Energy (IFE) parts of the program are given below. Consistent with the recommendations of the NRC report, these goals reflect both the science and energy aspects of the FES program.

<u>MFE Program Goals</u>

- Advance the fundamental understanding of plasma, the fourth state of matter, and enhance predictive capabilities, through the comparison of well-diagnosed experiments, theory and simulation.
- Resolve outstanding scientific issues by investigating a broad range of innovative plasma confinement configurations.
- Advance understanding and innovation in high-performance plasmas, and participate in a burning plasma experiment.

- Develop the technologies needed to advance fusion science; pursue innovative technologies and materials to improve the long-range vision for fusion energy.

<u>IFE Program Goals</u>

- Advance the fundamental understanding and predictability of high energy density plasmas for IFE, leveraging from the Inertial Confinement Fusion (ICF) target physics work sponsored by the National Nuclear Security Agency (NNSA).
- Develop the science and technology of attractive repetition-rated IFE power systems.

Each set of goals is derived from different program imperatives that have evolved over time.

For MFE and IFE, the imperatives included the continued development of fundamental scientific understanding and innovative technologies through the advancement of innovative concepts.

For MFE, in addition, the international fusion effort, including construction decisions for major next-step experiments, defines a broad context and a possible time frame for the MFE program.

For IFE, the program is paced by the need to obtain critical high energy density physics information from NNSA-funded programs, including the National Ignition Facility and other facilities. Another imperative is the eventual initiation of an Integrated Research Experiment that would integrate IFE elements, including a driver and target chamber. These two imperatives provide a possible time frame for the IFE program.

Program Objectives

<u>Management Objectives</u>

- Deliver excellent research in plasma science, fusion science and fusion technology, cognizant of DOE mission needs as well as the needs of the broad national science agenda.
- Provide national and international leadership in select areas of plasma science, fusion science, and fusion technology.
- Be the steward for plasma science, fusion science, and fusion technology at the DOE laboratory complex and research facilities, and for the scientific and technical workforce, providing the infrastructure to meet elements of the Nation's science agenda now and in the future. Ensure that the fusion research program is effectively integrated to produce results that advance the program's mission while working to build effective, mutually beneficial connections with other fields of science.
- Manage the fusion program's human resources and the operations of the national fusion science user facilities to the highest standards for efficiency, productivity, and safety. Use peer reviews and merit evaluations to plan, select, implement, and review fusion energy sciences programs.
- Enhance the effectiveness of available U.S. funding through mutually beneficial collaborative activities with fusion programs abroad.
- Coordinate with the NNSA's Office of Defense Programs on IFE.
- Continue to educate and train young scientists who will contribute broadly to the Nation's progress in many fields of science and technology.

Evaluation of Objectives

In October 2000, the NRC Fusion Assessment Committee released a draft of its final report "An Assessment of the Department of Energy's Office of Fusion Energy Sciences Program." The NRC concluded that the U.S. FES program "… has made remarkable strides over the years … Significant progress has been made in understanding and controlling instabilities and turbulence in plasma fusion experiments, facilitating improved plasma confinement. … Many of the major experimental and theoretical tools that have been developed are now converging to produce a qualitative change in the approach to scientific discovery in the program." The Committee concluded "… the quality of science funded by the United States fusion research program …is easily on a par with other leading areas of contemporary physical science." It recommended:

- making the scientific understanding of fusion plasmas a major program goal.
- initiating a systematic effort to reduce the isolation of the fusion research community from the rest of the scientific community.
- broadening the program's institutional base into the wider scientific community.
- establishing a new frontier plasma science center, even in a level budget scenario.
- developing solid support within the broad scientific community for U.S. investment in a burning plasma experiment.
- involving the NSF in extending the reach of fusion science and sponsoring general plasma research.

FES evaluates the progress being made toward achieving its scientific and management objectives in a variety of ways. Regular peer review and merit evaluation is conducted on all funded activities based on the procedures contained in 10 CFR 605 for the extramural grant program and under a similar but modified process for the laboratory programs and scientific user facilities. At least 80% of all new research projects supported by FES will be selected using a competitive peer review process.

The overall quality of the research in the FES program will be judged excellent and relevant by peers, and through various forms of external recognition.

Leadership in key FES disciplines that are critical to DOE's mission and the Nation will be measured through external review and other mechanisms.

Upgrades, construction and decommissioning of FES scientific user facilities will keep within 10 percent, on average, of cost and schedule milestones.

Operational downtime of FES operated facilities will be less than 10 percent of total operating time; this includes the three major fusion experimental facilities, DIII-D, Alcator C-Mod, and NSTX.

Ensure the safety and health of the workforce and members of the public and the protection of the environment in all its program activities.

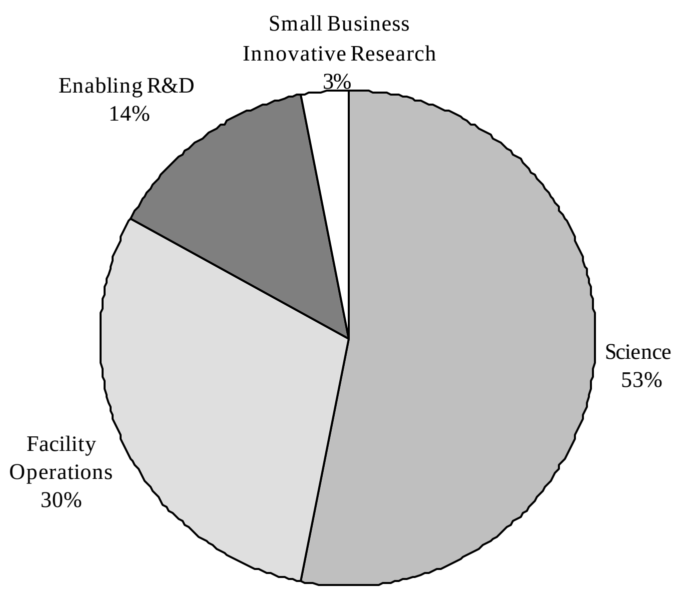
<u>Program Organization</u>

To meet the program objectives, the FES program is organized into three subprograms:

- The Science subprogram includes funds for general plasma science; for experiments on the physics of high temperature plasmas in various magnetic field configurations; for the physics of inertial fusion energy drivers; and for theory and modeling of fusion plasmas.

- The Facility Operations subprogram includes funds for building, operating, upgrading and decommissioning major facilities, and for infrastructure and waste management at the Princeton Plasma Physics Laboratory (PPPL).
- The Enabling R&D subprogram includes funds for the development of innovative technologies and materials research. The technologies support the enhancement of the operational capabilities of experimental facilities as well as the exploration of innovative advances for possible future facilities. The materials science activities are aimed at understanding the fundamental behavior of materials in the harsh fusion environment where they are bombarded by high-energy neutrons, and subjected to radiation, high heat fluxes, high magnetic fields and high temperatures.

In addition, the program includes funding for the Small Business Innovation Research program (SBIR) and the Small Business Technology Transfer program (STTR).



The FES FY 2002 Budget Request is $238.5 million

During the next four years, we expect:

significant progress in understanding the science of high temperature plasmas in magnetic fields,

decisions by the European Union, Japan, and Russia on the construction of major next-step fusion facilities of significant scientific importance, and

clarification of the availability of NNSA-funded facilities such as the National Ignition Facility.

The FES program will use these inputs to make assessments of possible U.S. participation in any international fusion collaborations, while aiming toward making more fundamental decisions at the end of that 4-year period about the future evolution of the U.S. domestic fusion program.

In FY 2002 the FES program will:

- address the recommendations of the NRC review to the extent possible.
- maintain the balance among science and technology elements as recommended by SEAB, NRC, and FESAC.
- provide for use of the U.S. program's unique experimental facilities to add to our understanding of the key physics issues governing toroidal fusion concepts. The three major facilities have complementary size, shape, and operating parameter regimes. All three programs are investigating stability, transport, and boundary layer plasma physics in the regimes accessible to each device. Key physics questions such as anomalous electron transport, stabilization of slow-growing instabilities (important to achieving steady state operation), and investigation of off-axis radio-frequency or microwave current drive as a means of plasma confinement and stability control will be the focus of experiments. There is increased effort in coupling together diagnostics, experiments and theory/modeling in order to better understand the results and compare them in different parameter regimes. These experiments are expected to contribute significantly to an assessment of the U.S. fusion program in the next four years, as recommended by FESAC.
- continue to participate in mutually beneficial international collaborative activities to advance understanding through pooling of scarce intellectual, experimental, and financial resources.
- continue to be ready to capitalize on advances in the worldwide fusion effort and the NNSA-funded inertial fusion target physics program.
- continue the Scientific Discovery through the Advanced Scientific Computing initiative to develop integrated models of both magnetic and inertial fusion systems.
- continue work on innovative confinement concept experiments (mostly at universities) that have resulted from competitive solicitations.
- continue fabrication of new, high current modules that will be used to upgrade and replace existing heavy ion accelerator physics facilities, allowing unique new studies of beam dynamics and instabilities. The results will be of interest to the beam and accelerator physics communities at large.
- continue innovative technology research efforts that will enable the achievement of major scientific goals on experimental fusion facilities in areas such as tritium science, the physics of high-power microwave heating, and very high heat flux interactions with solid and liquid surfaces. The innovations to be pursued will be determined using a competitive peer review process.
- meet our programmatic responsibilities by proceeding in a safe manner to complete the decontamination and decommissioning of the Tokamak Fusion Test Reactor (TFTR) and removing most or all of the recoverable tritium stored at the Tritium Systems Test Assembly (TSTA) facility at Los Alamos National Laboratory (LANL).

Scientific Facilities Utilization

The Fusion Energy Sciences request includes $91,717,000 to operate and make use of major fusion scientific user facilities. The Department's three major fusion energy physics facilities are: the DIII-D tokamak at General Atomics in San Diego, California; the Alcator C-Mod tokamak at the Massachusetts Institute of Technology; and the National Spherical Torus Experiment at the Princeton Plasma Physics Laboratory. These three facilities are each unique in the world's fusion program and offer opportunities to address specific fusion science issues that will contribute to the expanding knowledge base of fusion. Taken together, these facilities represent more than an $850,000,000 capital investment by the U.S. Government, in current year dollars.

The funding requested will provide research time for about 500 scientists in universities, federally sponsored laboratories, and industry, and will leverage both federally and internationally sponsored research, consistent with a strategy for enhancing the U.S. National science investment.

Significant Accomplishments and Program Shifts

Science

SCIENCE ACCOMPLISHMENTS

Research funded by the Fusion Energy Sciences program in FY 2000 produced major scientific results over a wide range of activities. Examples of these results include:

- Researchers have discovered a powerful tool for creating and manipulating desired “internal transport barriers” which prevent unwanted heat leakage from magnetically confined fusion plasmas. At the Alcator C-Mod, researchers are developing a technique known as “off-axis ion cyclotron radio frequency” (ICRF) heating. Normally, hot ions in plasmas circle around the magnetic field at different rates; the ions’ resulting “cyclotron frequencies” vary according to their positions in the tokamak. For reasons not completely understood, the overall plasma rotates around the tokamak. In traditional techniques for heating the plasma with radio waves, researchers send in waves with a frequency that matches the cyclotron frequency of ions at the center of the plasma. However, when this frequency matching location was moved off the center of the plasma, the rotation profile of the plasma was significantly changed. Simultaneously with this change, a clear internal transport barrier can develop, resulting in an extraordinary peaking of the plasma density, one that can be at least two times greater than without off-axis heating.
- Recent experiments in Germany and the United States have shown that fusion energy content and other properties in magnetically confined plasmas can be significantly improved by a relatively small amount of microwave power applied at precisely the right location in the plasma. Tokamak plasmas and, indeed, most magnetically trapped plasmas are subject to the growth of “magnetic islands.” These islands break up the smooth magnetic field surfaces that confine the plasma, leading to more rapid loss of heat from the plasma and making it more difficult to reach the high temperatures and pressures needed for nuclear fusion. Experiments first carried out in Germany and, more recently, in the DIII-D tokamak have confirmed theoretical predictions that islands due to high plasma pressure can be eliminated by adding a small amount of electrical current at the island location. A narrow beam of microwaves can drive the desired current in the plasma, with surgical precision, by interacting with electrons at the appropriate location. In recent experiments, a magnetic island degraded the plasma pressure by about 20%. Adding one megawatt of microwave power, about one-tenth of the total power needed to heat the plasma, drove enough current to suppress the island. This allowed the plasma pressure to recover, resulting in an increase in the energy content in the DIII-D plasma. These pioneering experiments show the feasibility of improving the temperature and density of fusion plasmas by small, precisely controlled modifications of their internal structure.
- Scientists have made use of magnetic reconnection, which underlies events in the sun’s corona, to help drive current in the National Spherical Torus Experiment, a new magnetic fusion device at the Princeton Plasma Physics Laboratory. It is called a “spherical torus” (ST) because the surface of the

plasma in it is shaped like a sphere with a narrow hole through the center. To maintain plasma confinement in an ST and to help heat the plasma, a strong electric current, encircling the central hole, must be driven in the plasma. In December 1999, NSTX reached a primary design goal by operating with one million amperes of current induced in the plasma by a solenoid (a spool-shaped coil) passing through the central hole. In addition to this traditional way of driving the plasma current, the researchers are developing a new method for producing this current. Known as coaxial helicity injection (CHI), this technique involves injecting an electric current directly from coaxial circular electrodes inside the plasma chamber, in the presence of an applied magnetic field.

- The current loops formed during CHI have similarities to the coronal loops seen on the sun's outer surface during solar flares. Just as in the solar corona, these loops can become unstable and relax to a lower energy state through a process known as magnetic reconnection. In the case of the ST, this lower energy state is one in which some of the current flows on field lines that close on themselves inside the vessel to form a confined plasma core. Whereas the traditional technique of inducing the current with a solenoid can only produce brief bursts of plasma current in an ST, the CHI technique holds promise for helping them to operate continuously.
- A modular energy transport computer code that can be accessed from the Internet was developed based on modern computing techniques. Theory based transport models, deduced from numerical studies of transport driven by strong turbulence are included in the code. The code is a first step to allow experimentalists to use such a code to explain the development of energy transport barriers associated with the stabilization of turbulent fluctuations.
- Scientists have applied a new theoretical model to explain the onset of plasma rotation observed in Alcator C-Mod prior to the transition to an improved confinement regime. The theory is that edge oscillations in the plasma propagate toward the center, carrying angular momentum. This causes the plasma to spin up and make a transition to a more energetic plasma. This is analogous to proposed explanations for the creation of rotating accretion disks observed around black holes in space.

FACILITY ACCOMPLISHMENTS

- Three new, innovative concept exploration experiments—the Translation, Confinement, and Sustainment (TCS) field reversed configuration experiment, and the flow-through Z-Pinch (ZaP) experiment, both at the University of Washington, and the Pegasus quasi-spherical torus experiment at the University of Wisconsin—became fully operational and have begun providing basic scientific understanding of plasma science phenomena. These include the creation of equilibrium plasma states, stabilization of kink instabilities by sheared flow, resolution of internal magnetic field configurations, and stability limits as a function of relevant plasma parameters.
- The Department jointly funded with NSF the operation of a new large-scale plasma science user facility at UCLA. The facility will be funded through an NSF cooperative agreement and jointly managed by NSF and DOE. The Large Plasma Device at UCLA is a flexible and low maintenance device for studying a variety of waves and nonlinear effects in fully magnetized plasmas.

Facility Operations

FACILITY ACCOMPLISHMENTS

In FY 2000, funding was provided to operate facilities in support of fusion research experiments and to upgrade facilities to enable further research in fusion and plasma science. Examples of accomplishments in this area include:

- The National Spherical Torus Experiment (NSTX) was operated with plasma currents of 500,000 amperes for periods of one-half second, and with plasma currents of 1 million amperes for shorter times. The program goal is to operate at 1 million amperes for one second. Installation of a neutral beam plasma heating system has been completed, providing a significant enhancement in physics research capability. The neutral beam provides both needed heating to the core of the plasma and an important enhancement to the range of plasma diagnostic systems that depend upon the perturbing aspects of the neutral beam and/or its byproducts.
- The cost of the TFTR D&D activities at PPPL was reduced by about $4,000,000 to $43,300,000 by removing the tritium from the tritium systems and components and then storing the equipment at the laboratory instead of shipping the equipment off site for disposal. Technical reviews confirmed that this equipment will retain much of its value for possible future use within the fusion program.
- After many years of successful and productive tritium handling technology research at TSTA, research operations have been completed. A new tritium laboratory, selected by competitive peer review, is being sited at an existing INEEL facility. Compared to TSTA, the INEEL laboratory will operate with much lower cost and tritium inventories, focusing on basic scientific issues of tritium use and behavior for a wide spectrum of Fusion Energy Sciences program elements.

Enabling R&D

SCIENCE ACCOMPLISHMENTS

- While the U.S. fusion program severed all ties with the ongoing ITER project in FY 1999, it continued to collaborate with Japan under the US-Japan Bilateral Agreement to test the ITER Central Solenoid Model Coil. The United States designed and fabricated the inner module of the coil before it was shipped to Japan for testing. The Model Coil is the largest pulsed superconducting magnet ever built. Test results have demonstrated that the coil meets or exceeds all of its performance objectives. This accomplishment is an important landmark for the scientific understanding of superconducting magnet behavior for fusion, and for potential applications of this technology in other fields.
- Scientists at PPPL conducted initial experiments in a toroidal plasma to investigate phenomena of plasma contact with liquid surfaces and guide development of models for plasma-liquid interactions critical to research on innovative concepts for plasma particle removal and surface heat flux removal. Such capabilities could be readily used for scientific studies in plasma experiments to control key parameters of the plasma edge, such as plasma particle density and temperature, and to carry away intense surface heat locally deposited by the plasma at its edge. For the longer-term, liquid surface technology can provide for much longer lifetimes and higher performance plasma-facing components than is possible with conventional solid surface approaches.
- Researchers at ORNL developed models for molecular dynamics, and dislocation dynamics for an atomistic description of microstructural evolution in ferritic steels under simulated conditions associated with fusion. These models unify and integrate the theories on mechanisms that control damage production from energetic neutron bombardment. Also, the models enable nanosystem methods for designing ferritic steel alloys with significantly improved performance and lifetimes, and with elemental tailoring that minimizes radioactivity generation by neutron-induced transmutation. The ability to produce superior metal alloys for fusion applications is critical to the viability of using fusion energy for practical applications with benign environmental impacts.
- Relative to non-metallic materials for fusion, such as ceramic composites based on silicon carbide, research in tailored nanoscale microstructures are producing remarkable advances in achieving high

ductility and radiation damage resistance. Crack reflecting interfaces deposited in ceramic composites are providing greatly improved toughness and micromechanical models are providing tools for predicting and controlling the growth of cracks that could lead to structural failures.

Awards

- Twelve fusion researchers were elected Fellows of the American Physical Society in 2000.
- A PPPL scientist received the Presidential Early Career Award and the DOE Office of Science Early Career Award
- A leading fusion scientist received the American Physical Society's 2000 Nicholson Award for Humanitarian Service.
- The head of the Engineering Department at PPPL received the 2000 Outstanding Achievement Award from the American Nuclear Society's Fusion Energy Division
- An INEEL scientist received the Woman's Achievement Award from the American Nuclear Society
- An INEEL scientist received the Outstanding Technical Accomplishment Award from the Fusion Energy Division of the American Nuclear Society
- A former Bell Laboratories scientist received the American Physical Society's James Clerk Maxwell Prize for Plasma Physics for important contributions to theoretical plasma physics
- A New York University professor was awarded an honorary doctorate by the order of the French Education Minister. The honorary degree makes the award winner an adjunct professor at the University of Provence
- A PPPL scientist was elected President of IEEE-USA
- An MIT professor received the Robert L. Woods Award from the Advisory Group on Electronics of the Department of Defense
- A LLNL scientist was elected Fellow of the American Association for the Advancement of Science
- A PPPL scientist received the Award for Outstanding Doctoral Thesis in Plasma Physics, Division of Plasma Physics, American Physical Society, (Oct. 2000)
- A University of California, San Diego professor received the APS 2000 Nicholson Medal for Humanitarian Assistance

PROGRAM SHIFTS

The budget requested for FY 2002 is reduced below the FY 2001 adjusted appropriation level. Reductions across most program elements have been made to cover this reduction, as well as to provide additional funds to LANL necessary for tritium clean up at the TSTA facility before it can be turned over to Environmental Management for Decontamination and Decommissioning.

Workforce Development

The FES program, the Nation's primary sponsor of research in plasma physics and fusion science, supports development of the R&D workforce by funding undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed as a part of this program provides new scientific talent to areas of fundamental research. It also provides talented people to a wide variety of technical and industrial fields that require finely honed thinking and problem solving abilities and computing and technical skills. Scientists trained through association with the FES program are employed in related fields such as plasma processing, space plasma physics, plasma electronics, and accelerator/beam physics as well as in other fields as diverse as biotechnology and investment and finance.

In FY 2000, the FES program supported 365 graduate students and post-doctoral investigators. Of these, 50 conducted research at the DIII-D tokamak at General Atomics, the C-Mod tokamak at MIT, or the NSTX at PPPL.

Two of the first five participants in the Junior Faculty in Plasma Physics Development Program have been granted tenure by their institutions.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Fusion Energy Sciences					
Science	130,326	139,820	-3,508	136,312	133,440
Facility Operations	73,706	79,812	-1,916	77,896	71,994
Enabling R&D	34,228	35,368	-1,083	34,285	33,061
Subtotal, Fusion Energy Sciences	238,260 [a]	255,000	-6,507	248,493	238,495
General Reduction	0	-2,596	2,596	0	0
General Reduction for Safeguards and Security	0	-3,363	3,363	0	0
Omnibus Rescission	0	-548	548	0	0
Total, Fusion Energy Sciences	238,260 [b] [c]	248,493	0	248,493	238,495 [d]

Public Law Authorization:
Public Law 95-91, "Department of Energy Organization Act"
Public Law 103-62, "Government Performance and Results Act of 1993"

[a] Excludes $5,748,000, which has been transferred to the SBIR program and $345,000 which has been transferred to the STTR program.

[b] Includes $2,984,000 for Waste Management activities at Princeton Plasma Physics Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $3,317,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

[d] In addition, $10,000,000 will be transferred to this activity in a Budget Amendment to be submitted shortly. Details will be provided at that time.

Funding By Site

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	6,741	6,826	7,629	+803	+11.8%
National Renewable Energy Laboratory ..	50	0	0	0	0.0%
Sandia National Laboratories	3,249	3,181	2,996	-185	-5.8%
Total, Albuquerque Operations Office	10,040	10,007	10,625	+618	+6.2%
Chicago Operations Office					
Argonne National Laboratory	2,321	2,406	2,009	-397	-16.5%
Princeton Plasma Physics Laboratory	65,784	70,589	66,702	-3,887	-5.5%
Chicago Operations Office.....................	45,718	43,712	41,803	-1,909	-4.4%
Total, Chicago Operations Office..................	113,823	116,707	110,514	-6,193	-5.3%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	1,568	2,210	2,082	-128	-5.8%
Oakland Operations Office					
Lawrence Berkeley National Laboratory ..	5,534	5,171	4,767	-404	-7.8%
Lawrence Livermore National Laboratory	14,894	14,714	14,189	-525	-3.6%
Stanford Linear Accelerator Center	49	0	0	0	0.0%
Oakland Operations Office	71,631	69,547	65,483	-4,064	-5.8%
Total, Oakland Operations Office	92,108	89,432	84,439	-4,993	-5.6%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education .	821	835	798	-37	-4.4%
Oak Ridge National Laboratory	18,369	16,116	16,412	+296	+1.8%
Oak Ridge Operations Office	17	39	0	-39	-100.0%
Total, Oak Ridge Operations Office	19,207	16,990	17,210	+220	+1.3%
Ohio Field Office...	8	0	0	0	0.0%
Richland Operations Office					
Pacific Northwest National Laboratory	1,369	1,427	1,317	-110	-7.7%
Washington Headquarters	137	11,720	12,308	+588	+5.0%
Total, Fusion Energy Sciences	238,260 [abc]	248,493	238,495 [d]	-9,998	-4.0%

[a] Excludes $5,748,000, which has been transferred to the SBIR program and $345,000 which has been transferred to the STTR program.

[b] Includes $2,984,000 for Waste Management activities at Princeton Plasma Physics Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $3,317,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

[d] In addition, $10,000,000 will be transferred to this activity in a Budget Amendment to be submitted shortly. Details will be provided at that time.

Site Description

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700-acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. Argonne's Fusion Energy Sciences program contributes to a variety of enabling R&D program activities. Argonne has a lead role internationally in analytical models and experiments for liquid metal cooling in fusion devices. Studies of the interaction of flowing liquid metals with magnetic fields are conducted in the ALEX facility. Studies of corrosion in candidate structural alloy materials are conducted in a liquid lithium flow loop. Argonne's capabilities in the engineering design of fusion energy systems have contributed to the design of components, as well as to analysis supporting the studies of fusion power plant concepts. Argonne also contributes to materials research with its unique capabilities in vanadium alloy testing in fission reactors and post-irradiation examinations.

Idaho National Engineering and Environmental Laboratory

Idaho National Engineering and Environmental Laboratory (INEEL) is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. Since 1978, INEEL has been the Fusion Energy Sciences program's lead laboratory for fusion safety. As the lead laboratory, it has helped to develop the fusion safety database that will demonstrate the environmental and safety characteristics of both nearer term fusion devices and future fusion power plants. Research at INEEL focuses on the safety aspects of both magnetic and inertial fusion concepts for existing and planned domestic experiments, and developing further our domestic safety database using existing collaborative arrangements to conduct work on international facilities. In addition, with the shutdown of the Tritium Systems Test Assembly (TSTA) facility at LANL, INEEL will expand their research and facilities capabilities to include tritium science activities.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is a Multiprogram Laboratory located in Berkeley, California. The Laboratory is on a 200-acre site adjacent to the Berkeley campus of the University of California. For the Fusion Energy Sciences program, the laboratory's mission is to study and apply the physics of heavy ion beams and to advance related technologies for the U.S. Inertial Fusion Energy program.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on an 821-acre site in Livermore, California. LLNL works with the Lawrence Berkley National Laboratory on the Heavy Ion Fusion program. The LLNL program also includes collaborations with General Atomics on the DIII-D tokamak, construction of an innovative concept experiment, the Sustained Spheromak Physics Experiment (SSPX) at LLNL, and benchmarking of fusion physics computer models with experiments such as DIII-D.

Los Alamos National Laboratory

Los Alamos National Laboratory is a Multiprogram Laboratory located on a 27,000-acre site in Los Alamos, New Mexico. The budget supports the creation of computer codes for modeling the stability of plasmas, as well as work in diagnostics, innovative fusion plasma confinement concepts such as Magnetized Target Fusion, and the removal of most of the recoverable tritium in FY 2002 from the Tritium Systems Test Assembly facility.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE), operated by Oak Ridge Associated Universities (ORAU) through a management and operating contract with DOE, is located on a 150-acre site in Oak Ridge, Tennessee. Established in 1946, ORAU is a consortium of 88 colleges and universities. The institute undertakes national and international programs in education, training, health, and the environment. For the FES program, ORISE supports the operation of the Fusion Energy Sciences Advisory Committee. It also acts as an independent and unbiased agent to administer the Fusion Energy Sciences Graduate and Postgraduate Fellowship Programs, in conjunction with FES, the Oak Ridge Operations Office, participating universities, DOE laboratories, and industries.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000-acre site in Oak Ridge, Tennessee. ORNL develops a broad range of components that are critical for improving the research capability of fusion experiments located at other institutions and that are essential for developing fusion as an environmentally acceptable energy source. The laboratory is a leader in the theory of heating of plasmas by electromagnetic waves, antenna design, and design and modeling of pellet injectors to fuel the plasma and control the density of plasma particles. Research is also done in the area of turbulence and its effect on the transport of heat through plasmas. Computer codes developed at the laboratory are also used to model plasma processing in industry. While some ORNL scientists are located full-time at off-site locations, others carry out their collaborations with short visits to the host institutions, followed by extensive computer communications from ORNL for data analysis and interpretation, and theoretical studies. ORNL leads the advanced fusion structural materials science program, contributes to research on all materials systems of fusion interest, coordinates experimental collaborations for two U.S.-Japan programs, and coordinates materials activities for the Virtual Laboratory for Technology.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The Fusion Energy Sciences program at PNNL is focused on research on materials that can survive in a fusion neutron environment. The available facilities used for this research include mechanical testing and analytical equipment, including state-of-the-art electron microscopes, that are either located in radiation shielded hot cells or have been adapted for use in evaluation of radioactive materials after exposure in fission test reactors. Experienced scientists and engineers at PNNL provide leadership in the evaluation of ceramic matrix composites for fusion applications and support work on vanadium, copper and ferritic steels as part of the U.S. fusion materials team. PNNL also plays a leadership role in a fusion materials collaboration with Japan, with Japanese owned test and analytical equipment located in PNNL facilities and used by both PNNL staff and up to ten Japanese visiting scientists per year.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory (PPPL) is a program-dedicated laboratory (Fusion Energy Sciences) located on 72 acres in Princeton, New Jersey. PPPL is the only U.S. Department of Energy (DOE) laboratory devoted primarily to plasma and fusion science. It hosts experimental facilities used by multi-institutional research teams and also sends researchers and specialized equipment to other fusion facilities in the United States and abroad. PPPL is the host for the National Spherical Torus Experiment (NSTX), which is an innovative toroidal confinement device closely related to the tokamak, and is currently working on the conceptual design of another innovative toroidal concept, the compact stellarator. PPPL scientists and engineers have significant involvement in the DIII-D and Alcator C-Mod tokamaks in the U.S. and the large JET (Europe) and JT-60U (Japan) tokamaks abroad. This research is focused on developing the scientific understanding and innovations required for an attractive fusion energy source. PPPL scientists are also involved in several basic plasma science experiments, ranging from magnetic reconnection to plasma processing. PPPL, through its association with Princeton University, provides high quality education in fusion-related sciences, having produced more than 175 Ph.D. graduates since its founding in 1951.

Sandia National Laboratory

Sandia National Laboratory is a Multiprogram Laboratory, located on a 3,700 acre site in Albuquerque, New Mexico, with other sites in Livermore, California, and Tonopah, Nevada. Sandia's Fusion Energy Sciences program plays a lead role in developing components for fusion devices through the study of plasma interactions with materials, the behavior of materials exposed to high heat fluxes, and the interface of plasmas and the walls of fusion devices. Sandia selects, specifies, and develops materials for components exposed to high heat and particles fluxes and conducts extensive analysis of prototypes to qualify components before their use in fusion devices. Materials samples and prototypes are tested in Sandia's Plasma Materials Test Facility, which uses high-power electron beams to simulate the high heat fluxes expected in fusion environments. Materials and components are exposed to tritium-containing plasmas in the Tritium Plasma Experiment. Tested materials are characterized using Sandia's accelerator facilities for ion beam analysis. Sandia supports a wide variety of domestic and international experiments in the areas of tritium inventory removal, materials postmortem analysis, diagnostics development, and component design and testing.

All Other Sites

The Fusion Energy Sciences program funds research at more than 50 colleges and universities located in approximately 30 states. It also funds the DIII-D tokamak experiment and related programs at General Atomics, an industrial firm located in San Diego, California.

Science

Mission Supporting Goals and Objectives

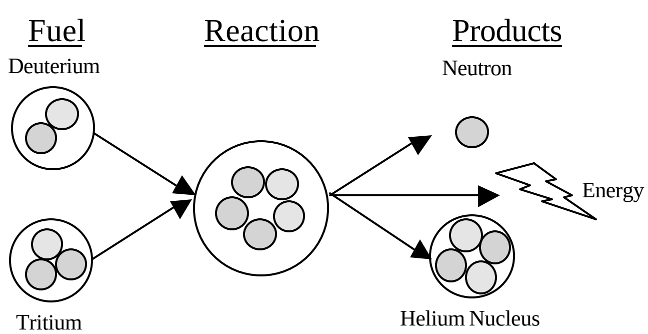
The goals of the Science subprogram are to understand the elementary physical processes that occur in plasmas and to use this knowledge to develop innovative approaches for confining fusion plasmas. These goals are accomplished by conducting:

- theory and modeling programs to develop the fundamental principles for understanding the complex behavior of plasmas
- research programs on fusion-relevant plasma experiments
- diagnostic development programs that provide improved instruments to measure plasma parameters such as temperature, density, and magnetic field strengths, and their fluctuations, over a wide range of parameters and time scales in a variety of experimental configurations, making possible rigorous comparisons between experiment and theory/modeling

A companion goal of the Science subprogram is to broaden the intellectual and institutional base in fundamental plasma science. Two activities, an NSF/DOE partnership in plasma physics and engineering and development grants for junior members of university plasma physics faculties, have been the major contributors to this objective.

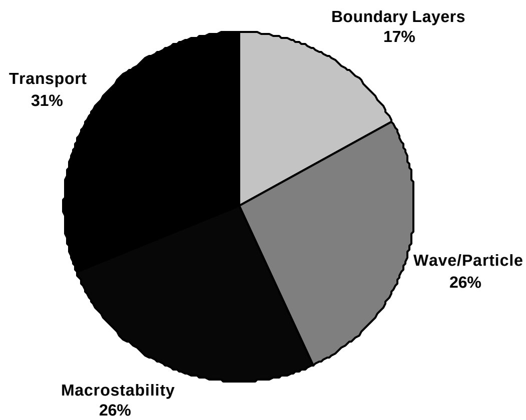
Plasma science is the study of the ionized matter that makes up 99 percent of the observable universe, ranging from neon lights to stars. It includes not only plasma physics but also other physical phenomena in ionized matter, such as atomic, molecular, radiation-transport, excitation and ionization processes. These phenomena can play significant roles in partially ionized media and in the interaction of plasmas with material walls. Plasma science contributes not only to fusion research, but also to many other fields of science and technology, such as astrophysics and industrial processing, and to national security.

Fusion science is focused primarily on describing the fundamental processes taking place in plasmas where the temperatures (greater than 100 million degrees Celsius) and densities permit hydrogenic nuclei that collide to fuse together, releasing energy and producing the nucleus of a helium atom and a neutron.



The Fusion Process

Fusion science shares many scientific issues with plasma science. For MFE, these scientific issues include: (1) wave-particle interaction and plasma heating; (2) chaos, turbulence, and transport; (3) sheaths and boundary layers; and (4) stability, magnetic reconnection, and dynamos. Progress in all of these research issues is likely to be required for ultimate success in achieving a practical fusion energy source.



Science subprogram estimated funding allocation to address the MFE science issues.

For IFE, the two science issues are: (1) high energy density physics, such as laser-plasma and beam-plasma interactions, and (2) non-neutral plasmas.

The largest component of the Science subprogram is research that focuses on gaining a predictive understanding of the behavior of the high temperature, high-density plasmas typically required for fusion energy applications. The tokamak magnetic confinement concept has thus far been the most effective approach for confining plasmas with stellar temperatures within a laboratory environment. Many of the important issues in fusion science are being studied in an integrated program on the two major U.S. tokamak facilities, DIII-D at General Atomics and Alcator C-Mod at the Massachusetts Institute of Technology. Both DIII-D and Alcator C-Mod are operated as national science user facilities with research programs established through public research forums, program advisory committee recommendations, and peer review.

DIII-D has extensive diagnostic instrumentation to measure what is happening in the plasma. It also has unique capabilities to shape the plasma, which, in turn, affects particle transport in the plasma and the stability of the plasma. DIII-D has been a major contributor to the world fusion program over the past decade in the areas of plasma turbulence, energy and particle transport, electron-cyclotron plasma heating and current drive, plasma stability, and boundary layer physics using a “magnetic divertor” to control magnetic field configuration at the edge of the plasma. (The divertor is produced by magnet coils that bend the magnetic field at the edge of the tokamak out into a region where plasma particles following the field are neutralized and pumped away.)

Alcator C-Mod is a unique, compact tokamak facility that uses intense magnetic fields to confine high temperature, high-density plasmas. It is also unique in the use of metal (molybdenum) walls to accommodate the high power densities in this compact device. Alcator C-Mod has made significant contributions to the world fusion program in the area of ion-cyclotron frequency wave-particle interaction and plasma heating.

In the future, both DIII-D and Alcator C-Mod will focus on using their flexible plasma shaping and dynamic control capabilities to attain good confinement and stability by controlling the distribution of current in the plasma with radio wave current drive and the interface between the plasma edge and the material walls of the confinement vessel with a "magnetic divertor." Achieving these high performance regimes for longer pulse duration will require simultaneous advances in all of the scientific issues listed above.

In addition to the advanced toroidal research on DIII-D and Alcator C-Mod, exploratory work will continue on two university tokamak experiments. The goal of the High Beta Tokamak (HBT) at Columbia University is to demonstrate the feasibility of stabilizing high plasma pressure within a tokamak configuration by a combination of a close-fitting conducting wall, plasma rotation, and active feedback. This work will be closely coordinated with the DIII-D program, and promising advances will be applied on DIII-D. The Electric Tokamak (ET) at UCLA will explore several new approaches to toroidal magnetic confinement; emphasizing radio wave driven plasma rotation and the achievement of very high plasma pressure relative to the applied magnetic field to produce a deep magnetic well.

The next largest research component is work on alternative concepts, aimed at extending fusion science and identifying concepts that may have favorable stability or transport characteristics that could improve the economic and environmental attractiveness of fusion energy sources. The largest element of the alternative concepts program is the National Spherical Torus Experiment (NSTX) at Princeton Plasma Physics Laboratory, which began its first full year of operation in FY 2000. Like DIII-D and Alcator C-Mod, NSTX is also operated as a national scientific user facility.

NSTX has a unique, nearly spherical plasma shape that complements the doughnut shaped tokamak and provides a test of the theory of toroidal magnetic confinement as the spherical limit is approached. Its favorable stability properties allow confinement at high plasma pressure relative to the applied magnetic field, and its high rate of shear for the flowing plasma should stabilize turbulence and lead to very good confinement. An associated issue for spherical torus configurations is the challenge of driving plasma current via radio-frequency waves or biasing electrodes. New computational and experimental techniques will be needed for the unique geometry and field configuration of the NSTX.

Exploratory research will continue, using more than a dozen small-scale, alternative concept devices and basic science experiments, to study only one or two scientific topics for which each experiment is optimized. For example, the Madison Symmetric Torus at the University of Wisconsin is a toroidal configuration with high current but low toroidal magnetic field that reverses direction near the edge of the discharge. The magnetic dynamo effect, which results from turbulent processes inside the plasma, spontaneously generates the field reversal at the plasma edge. This innovative experiment is investigating the dynamo mechanism, which is of interest in several fields of science including space and astrophysics, and turbulent transport, which is of interest in fusion science. The Levitated Dipole Experiment, a joint Massachusetts Institute of Technology/Columbia University program is exploring plasma confinement in a novel magnetic dipole configuration (similar to the magnetic fields constraining plasma in the earth's magnetosphere). At Princeton Plasma Physics Laboratory, the Magnetic Reconnection Experiment addresses fundamental questions in magnetic reconnection, the process by which currents and flows in a plasma can induce changes in the topology of the magnetic field by breaking and reconnecting magnetic field lines. Magnetic reconnection is important not only in fusion experiments but also in phenomena like the solar flares, the solar wind and astrophysical plasmas.

A different set of insights into stability properties of plasmas should be developed from investigations into new stellarator configurations taking advantage of advances in stellarator theory, new computational capabilities, and insights from recent tokamak research. These stellarator configurations are nearly axisymmetric (like a tokamak) but do not require an externally driven current to produce an equilibrium. Thus, they should have the transport properties similar to a tokamak but should have different stability properties. A national team is completing work on the design of a medium-size National Compact Stellarator Experiment (NCSX) that would be used to study plasma turbulence, energy and particle transport, and stability in this novel geometry. It will also strengthen U.S. involvement in the much larger world stellarator program.

An entirely different set of science explorations is being carried out in the area of high energy density plasma physics, the underlying field for Inertial Fusion Energy (IFE). In pursuing this science, the IFE activity is exploring an alternate path for fusion energy that would capitalize on the major R&D effort in inertial confinement fusion (ICF) carried out for stockpile stewardship purposes within the National Nuclear Security Agency (NNSA) Office of Defense Programs. The IFE program depends on the ICF program for experimental research into the high energy density physics required for the design of energy producing targets and for future testing of the viability of IFE targets in the National Ignition Facility at LLNL. Efforts in IFE focus on understanding the physics of systems that will be needed to produce a viable inertial fusion energy source. These include heavy ion beam systems for heating and compressing a target pellet to fusion conditions, the experimental and theoretical scientific basis for modeling target chamber responses, and the physics of high-gain targets. The physics of intense heavy ion beams and other non-neutral plasmas is both rich and subtle, due to the kinetic and nonlinear nature of the systems and the wide range in spatial and temporal scales involved. For these reasons, heavy ion beam physics is of interest to the larger accelerator and beam physics community. The modeling of the fusion chamber environment is very complex and must include multi-beam, neutralization, stripping, beam and plasma ionization processes, and return current effects.

The theory and modeling program provides the conceptual underpinning for the fusion sciences program. Theory efforts are challenged to describe complex non-linear plasma systems at the most fundamental level. These descriptions are modeled through highly sophisticated computer codes that are used to analyze data from current experiments, guide future experiments, design future experimental devices, and assess projections of their performance. Such codes represent a growing knowledge base that, in the end, is expected to lead to a predictive understanding of how fusion plasmas can be sustained and manipulated.

An important element of the theory and modeling program is the FES portion of the Office of Science's Scientific Discovery Through Advanced Computing program. Major scientific challenges exist in many areas of plasma and fusion science that can best be addressed through advances in scientific supercomputing, e.g., understanding and controlling plasma turbulence, investigating the physics of heavy ion accelerators, or understanding and controlling magnetohydrodynamic instabilities in magnetically confined plasmas.

The general plasma science program supports basic plasma science and engineering research and advances the discipline of plasma physics. Topics explored include a broad range of fundamental research efforts in wave-plasma physics, dusty plasmas, non-neutral plasmas, and boundary layer effects. Important elements of this program include the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Junior Faculty in Plasma Physics Development Program, and the basic and applied plasma physics program at DOE laboratories.

In FY 2000, the NSF/DOE Partnership funded more than 30 principal investigators who were chosen in a competitive peer review process from over 160 proposals to receive awards totaling about $4,000,000. Three new Junior Faculty in Plasma Physics were also awarded via competitive review.

The recent National Academy of Science assessment of the Fusion Energy Sciences program recommended the establishment of frontier plasma science centers. DOE would seek joint funding from other agencies to establish these centers through a competitive solicitation process that would include cost sharing by the participating institutions. The centers would involve multidisciplinary teams from universities and national labs, and provide the opportunities to broaden the program's institutional base and encourage participation by the wider scientific community. Possible focus topics for the centers include turbulence and transport, magnetic reconnection, plasma dynamics, energetic particle dynamics, and fusion materials modeling. In FY 2001, the solicitation for proposals in advanced scientific computing seeks proposals for topical centers. Those selected, through competitive peer review, will be continued in FY 2002.

In addition to their work on domestic experiments, scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad. The Fusion Energy Sciences program has a long-standing policy of seeking collaboration internationally in the pursuit of timely scientific issues. Collaboration avoids duplication of facilities that exist abroad. These include the world's highest performance tokamaks (JET in England and JT-60 in Japan), a stellarator (the Large Helical Device) in Japan, a superconducting tokamak (Tore Supra) in France, and several smaller devices. In addition, the U.S. is collaborating with South Korea on the design of a long-pulse, superconducting, advanced tokamak (KSTAR). These collaborations provide a valuable link with the 80% of the world's fusion research that is conducted outside the U.S.

Finally, development of improved diagnostic tools for analyzing plasma behavior continues to provide new insights into fusion plasmas and enables the detailed comparison of fusion theory and experiments. Non-perturbing measurements of the dynamic temperatures, densities, and electromagnetic fields in the core of near-burning plasma presents a formidable challenge. Nonetheless, considerable progress in obtaining quantitative measurements has been made over the last decade. Balanced progress in theory and modeling, experimental operation, and the development of improved measurement systems has provided an excellent formula for scientific progress in fusion.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence, and relevance; quality; and safety and health.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Tokamak Experimental Research	46,546	44,980	45,014	+34	+0.1%
Alternative Concept Experimental Research	51,380	50,274	48,336	-1,938	-3.9%
Theory	24,270	27,275	25,975	-1,300	-4.8%
General Plasma Science	8,130	8,408	8,026	-382	-4.5%
SBIR/STTR	0	5,375	6,089	+714	+13.3%
Total, Science	130,326	136,312	133,440	-2,872	-2.1%

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
Tokamak Experimental Research	**46,546**	**44,980**	**45,014**
▪ **DIII-D Research**	**23,532**	**22,740**	**22,723**

The DIII-D tokamak facility provides the largest, well-diagnosed, high temperature experimental magnetic fusion facility in the U.S. The DIII-D experimental program is structured along the four key MFE fusion topical science areas — energy transport, stability, plasma-wave interactions, and boundary physics. In FY 2002, the level of participation by the collaborators and on site staff in physics research and data analysis will be decreased. Research in all four topical science areas will be pursued using the new microwave heating hardware modifications, a new diagnostic for current profile measurements, and enhanced computational tools. In particular, emphasis on testing different transport theories by comparison of experimental results and physics based computer models will increase. Control of stability limits, which has gone through an initial phase of experiments, will be further investigated by modification of current profiles with electron cyclotron waves. These studies are closely coupled to the theoretical basis for the instabilities. The installation of equipment that will allow 6 MW of electron cyclotron heating power to be injected into the plasma will be completed in the first quarter of FY 2002 at a cost of about $8,000,000; this heating power will be used to further verify the predicted current drive physics. The understanding and control of boundary physics is very critical for the control of energy transport in the plasma core. New diagnostics for current profile measurement are being installed in FY 2001, which will enhance the study of boundary physics, especially as to the nature of edge currents that lead to instabilities at the plasma edge. In FY 2002, **performance will be measured by** successful use of the recently upgraded plasma microwave heating system and new sensors on DIII-D to study feedback stabilization of disruptive plasma oscillations. This understanding could permit substantial increases in the effective containment of plasma pressure with a given magnetic field.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
▪ **Alcator C-Mod Research**..	**7,969**	**7,305**	**7,488**

The Alcator C-Mod facility, by virtue of its very high magnetic field, is particularly well suited to operate in plasma regimes that are relevant to future, much larger fusion tokamaks as well as to compact, high field burning plasma physics tokamaks. The approach to ignition and sustained burn of a plasma is an important integrating science topic for fusion. In FY 2002, the level of participation by the collaborators and on site staff in physics research and data analysis will be maintained at its current level. Research will be pursued to examine the physics of the plasma edge, power and particle exhaust from the plasma, mechanisms of self-generation of flows in the plasma, and the characteristics of the advanced confinement modes that appear in the plasma when currents are driven by radio waves. It will also focus on exploring physics techniques for radiating away the large parallel heat flow encountered in the plasma exhaust at high densities and on visualization diagnostics for turbulence in the edge and core of high density plasmas. A new diagnostic neutral beam, commissioned in FY 2000, will allow for improved comparisons between theory and experimental results on the characteristic behavior of the plasma.

▪ **International Collaborations and Education**......................	**7,642**	**7,784**	**7,987**

International collaboration provides the opportunity for U.S. scientists to work with their colleagues on unique foreign tokamaks (JET, Tore Supra, TEXTOR, and ASDEX-UG in Europe, JT-60U in Japan, and KSTAR in Korea). These collaborations produce complementary and comparative data to those obtained on the U.S. tokamaks to further the scientific understanding of fusion physics and enhance the pace of fusion energy development. In FY 2002, the collaboration with these programs will focus on ways of using the unique aspects of these facilities to make progress on the four key MFE issues cited in the FES Program Mission. Funding for educational activities in FY 2002 will support research at historically black colleges and universities, graduate and postgraduate fellowships in fusion science and technology, summer internships for undergraduates, general science literacy programs for teachers and students, and broad outreach efforts related to fusion science and technology.

▪ **Experimental Plasma Research (Tokamaks)**......................	**7,403**	**7,151**	**6,816**

Funding provided in this category supports research on innovative tokamak experiments at universities and the development of diagnostic instruments.

Several unique, innovative tokamak experiments are supported. In FY 2002, the High Beta Tokamak at Columbia will continue work on feedback stabilization of magnetohydrodynamic instabilities. Experiments in the Electric Tokamak at UCLA will continue to be directed at developing an understanding of the effects of plasma rotation at progressively higher levels of radio frequency heating power.

Development of unique measurement capabilities (diagnostic systems) that provide an understanding of the plasma behavior in fusion research devices will continue. This research provides the necessary information for analysis codes and theoretical interpretation. Some key areas of diagnostic research include the development of: (1) techniques to measure the cause of heat and particle loss from the core to the edge of magnetically confinement plasmas, including techniques aimed at understanding how barriers to heat loss can be formed in plasmas; (2) methods to measure the production, movement, and loss/retention of the particles that are needed to ignite and sustain a burning plasma; (3) new approaches that are required to measure plasma parameters in alternate magnetic configurations, which provide unique constraints due to magnetic field configuration and strength, and limited lines of sight into the plasma. The requested funding level in FY 2002 supports the highest-rated proposals of this multiyear diagnostic development research, as well as any new research programs that are recommended for funding as a result of a competitive peer review of the diagnostics development program.

	FY 2000	FY 2001	FY 2002
Alternative Concept Experimental Research	**51,380**	**50,274**	**48,336**
▪ **NSTX Research**	**12,379**	**12,125**	**12,000**

The NSTX is the one of the world's two largest embodiments of the spherical torus confinement concept. Plasmas in spherical tori have been predicted to be stable even when high ratios of plasma-to-magnetic pressure and self-driven current fraction exist simultaneously in the presence of a nearby conducting wall bounding the plasma. If these predictions are verified in detail, it would indicate that spherical tori use applied magnetic fields more efficiently than most other magnetic confinement systems and, could therefore, be expected to lead to more cost-effective fusion power systems in the long term.

Large plasma current can be produced by use of the magnetic reconnection technique called Coaxial Helicity Injection (CHI) which uses an innovative application of direct-voltage and current from the plasma edge to create the plasma. Scientists are investigating whether this technique can be integrated at plasma startup with the normal ohmic driven current. This could open up the additional possibility of integrating the CHI with other current drive techniques such as radio frequency waves and neutral beam injection. The intriguing physics properties of this innovative non-inductive startup technique have already been studied in small university size experiments in FY 2001. The basic mechanism is being systematically investigated in NSTX using improved control techniques. To date plasma currents of up to 200 kilo amps (kA) have just been successfully achieved. In FY 2002, **performance will be measured by** a successful demonstration of innovative techniques for initiating and maintaining the current in a spherical torus.

In FY 2002, the level of participation by the collaborators and on site staff in physics research and data analysis will be reduced. The NSTX research team will focus on evaluating the plasma stability limits with auxiliary heating. Procedures for operating NSTX while using an improved control system will be developed. This will include development of techniques for applying neutral beam heating early in the startup phase to permit stability studies and an assessment of the resulting plasma oscillations. In preparation for longer-term objectives, the fusion science research activities will concentrate on developing higher current capability (up to 500 kA) and further buildup of plasmas started in this way using conventional plasma heating methods to assess the potential of using CHI to extend NSTX plasma pulse length. Goals in FY 2002 include identifying the mechanisms for transporting plasma across the magnetic field at low aspect ratio over a wide range of plasma pressure as a fraction of magnetic pressure. One focus will be on comparing the measured dependence of energy and particle fluxes on background plasma variations including the twist of the magnetic field lines, and comparing these fluxes with theoretical predictions.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
▪ **Experimental Plasma Research (Alternatives)**..................	**24,799**	**24,357**	**23,184**

This budget category includes most of the experimental research on plasma confinement configurations outside of the three major national facilities described above. Funds in this category are provided for twelve small experiments, one intermediate level proof-of-principle experiment, and one large study program that is focused on obtaining a design for a compact stellarator proof-of-principle experiment.

The majority of the research is directed toward toroidal configurations (the toroidal direction is the long way around a magnetic "doughnut"). For configurations with a large toroidal magnetic field, the research is focused on stellarators with special combinations of confining magnetic fields. The Helically Symmetric Torus is the world's first stellarator designed using one simplified combination of such magnetic fields. As discussed above, there is also a significant effort underway that is studying the design of a larger stellarator similar to the tokamak, but with rotational transform generated by either external coils or externally driven plasma current (a hybrid). This pre-conceptual design effort for a National Compact Stellarator Experiment (NCSX) is using computer simulations to develop very compact stellarator configurations that appear to overcome some of the stability problems that have faced the tokamak design, at the cost of some complexity in coil design.

Two small spherical tori, the Helicity Injection Tokamak at the University of Washington and the Pegasus Experiment at the University of Wisconsin, are used in the experimental study of the physics of these compact toroidal shapes. Of particular interest for many of these small-scale experiments are methods used to form the magnetic shapes and to sustain them by injection of additional current in a controlled manner so that the configuration is not de-stabilized and destroyed.

Research on high energy density configurations in which the toroidal field is less than the poloidal (the short way around the magnetic "doughnut") field concentrates on pulse sustainment, confinement, and magnetic field reconnection (formation) processes. Many of these innovative experiments have relatively short pulses in comparison to tokamak discharges, and these experiments are investigating means of sustaining the pulse. These programs include the Madison Symmetric Torus (University of Wisconsin), a spheromak experiment at LLNL, and a small experiment at the California Institute of Technology designed to study the basic physics of the reconnection (formation) process itself.

Research on toroidal systems with the highest energy density includes systems with no toroidal magnetic field and relatively small poloidal magnetic fields. The field reversed configuration (FRC) experiment at the University of Washington, the world's most advanced experiment of this type, focuses on sustaining the relatively short pulses of these plasmas through novel electrical and plasma processes. The ion ring experiment at Cornell University seeks gross stabilization of the FRC through the use of large particle orbits in the magnetic fields (charged particles tend to move in circles in magnetic fields, hence the "orbit"). The levitated dipole experiment (LDX) at MIT will be studying a variant where the confining poloidal magnetic fields are generated by a superconducting magnetic ring located within the plasma itself. Dipole confinement is of great scientific interest in many solar and astrophysical plasma systems.

The magnetized target fusion program (funded by the FES program) at LANL and the Air Force Research Laboratory will study the possibility that a FRC plasma can be compressed to multi-keV temperatures using fast liner compression technology developed by the DOE Defense Programs.

In FY 2002, research efforts on most of these exploratory activities will continue. New concepts will be funded as appropriate through peer review.

	FY 2000	FY 2001	FY 2002
▪ **Inertial Fusion Energy Experiments**	**14,202**	**13,792**	**13,152**

The inertial fusion energy program has research components that encompass many of the scientific and technical elements that form the basis of an inertial fusion energy system. Heavy ion accelerators continue to be the leading IFE driver candidate. Understanding the physics of the intense heavy ion beam (Bi+4, for example), a non-neutral plasma, is one of the outstanding scientific issues. Considerable progress has been made on developing a predictive physics model for intense heavy ion beams. This model, which includes aspects of the accelerator system, has the goal of providing an “end to end” simulation of a heavy ion accelerator. Future developments will include final focusing and transport in the target chamber. The close interplay between scaled experiments and theory and calculation assures that the model has been validated against experiment. Technical elements of the program include the continuing development of experimental systems to study beam formation by high current ion sources, beam acceleration and focusing. The high current experiment under construction will be the primary experimental facility for heavy ion beam transport studies. The 500 kV test stand will be used to study the physics of intense ion sources. Physics experiments carried out on NNSA-funded facilities including the National Ignition Facility (NIF) will provide high energy density physics data to be used in the design of targets for IFE experiments. NIF will provide validation of target design for actual model targets. The IFE science program will be focused on scientific and technical elements that will allow progress toward future integrated experiments. In FY 2002, **performance will be measured by** successfully bringing into operation the recently completed 500 kV Ion Source Test Stand at LLNL, and by starting experiments to explore new ion source configurations to discover improved ways of producing heavy ion driver beam currents.

Performance will be measured by completing a preliminary technical assessment of technology issues and approaches for inertial fusion energy concepts in the areas of the high energy density plasma chambers, target fabrication and tracking, and target chamber interfaces, including studies of safety issues.

	FY 2000	FY 2001	FY 2002
Theory	**24,270**	**27,275**	**25,975**

The goal of the theory and computation program is to achieve a quantitative understanding of the behavior of fusion plasmas for interpreting experiments and for guiding the design of future devices. Considerable progress has been made in areas of macroscopic equilibrium and stability of magnetically confined plasmas and turbulence and transport in tokamak plasmas.

The theory and modeling development program is a broad-based program with researchers located at national laboratories, universities, and industry. The main thrust of the work in tokamak theory is aimed at developing predictive understanding of advanced tokamak operating modes. These tools will later be extended to innovative confinement geometries. In alternate concept theory, the emphasis is on

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

understanding the fundamental processes determining equilibrium, stability, and confinement in each concept. The generic theory work supports the development of basic plasma theory and atomic physics theory that is applicable to fusion research and to basic plasma science. A separate modeling effort is dedicated to developing computational tools to assist in the analysis of experimental data.

In FY 2002 the theory and computation program will continue to emphasize advanced computing and will make use of rapid developments in computer hardware to attack complex problems involving a large range of scales in time and space. These problems were beyond the capability of computers in the past, but advancements in computation are allowing a new look at problems that once seemed almost intractable. The objective of the advanced computing activities, including the Scientific Discoveries through Advanced Computing program, is to promote the use of modern computer languages and advanced computing techniques to bring about a qualitative improvement in the development of models of plasma behavior. This will ensure that advanced modeling tools are available to support a set of innovative national experiments and fruitful collaboration on major international facilities. Specific performance measures include the addition of electron dynamics in turbulence calculations and the inclusion of the plasma's self-generated currents in gross stability simulations. These additions will improve the fidelity of the simulations and provide an enhanced predictive understanding of fusion plasmas.

General Plasma Science	**8,130**	**8,408**	**8,026**

The general plasma science program is directed toward basic plasma science and engineering research. This research strengthens the fundamental underpinnings of the discipline of plasma physics, which makes contributions in many basic and applied physics areas, one of which is fusion energy. Principal investigators at universities, laboratories and private industry carry out the research. A critically important element is the education of plasma physicists. Continuing elements of this program are the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Junior Faculty in Plasma Physics Development Program and the basic and applied plasma physics program at DOE laboratories. In FY 2002, the program will continue to fund proposals that have been peer reviewed. Basic plasma physics user facilities will be supported at both universities and laboratories. Atomic and molecular data for fusion will continue to be generated and distributed through openly available databases.

SBIR/STTR	**0**	**5,375**	**6,089**

In FY 2000, $4,861,000 and $292,000 were transferred to the SBIR and STTR programs, respectively. The FY 2001 and FY 2002 amounts are the estimated requirements for the continuation of these programs. In the past, funding requirements for SBIR/STTR had been split between the Science and Enabling R&D subprograms. Beginning in FY 2002, all SBIR/STTR requirements will be funded in the Science subprogram.

Total, Science	**130,326**	**136,312**	**133,440**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Tokamak Experimental Research	
▪ Funding for DIII-D research is slightly reduced..	-17
▪ Funding for Alcator C-Mod research is increased by shifting funds from Alcator C-Mod operations to optimize the scientific productivity of the Alcator C-Mod program. .	+183
▪ An increase in funding for such support activities as education and HBCUs is partially offset by a decrease in international collaborations.	+203
▪ The level of funding for Tokamak Experimental Plasma Research is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-335
Total, Tokamak Experimental Research	+34
Alternative Concept Experimental Research	
▪ Funding for NSTX research is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-125
▪ Funding for alternate concept experiments at universities is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-1,173
▪ Funding for IFE science is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs	-640
Total, Alternative Concept Experimental Research	-1,938
Theory	
▪ Funding for theory and modeling to support experiments is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs	-1,300
Total, Theory	-1,300
General Plasma Science	
▪ The funds available for the NSF/DOE partnership is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-382
Total, General Plasma Science	-382

	FY 2002 vs. FY 2001 ($000)
SBIR/STTR	
▪ Support for SBIR/STTR is mandated at 2.65 percent. In the past, funding requirements for SBIR/STTR had been split between the Science and Enabling R&D subprograms. Beginning in FY 2002, all SBIR/STTR requirements will be funded in the Science subprogram.	+714
Total Funding Change, Science	-2,872

Facility Operations

Mission Supporting Goals and Objectives

This activity provides mainly for the operation and maintenance of major fusion research facilities; namely, DIII-D at GA, Alcator C-Mod at MIT, and NSTX at PPPL. These user facilities enable U.S. scientists from universities, laboratories, and industry, as well as visiting foreign scientists, to conduct the world-class research funded in the Science and Enabling R&D subprograms. The facilities consist of magnetic plasma confinement devices, plasma heating and current drive systems, diagnostics and instrumentation, experimental areas, computing and computer networking facilities, and other auxiliary systems. These funds pay for operating and maintenance personnel, electric power, expendable supplies, replacement parts, system modifications and facility enhancements. Capital equipment funding for upgrading and enhancing the research capability of DIII-D and C-Mod is also included.

Funding is included in this subprogram for several activities at PPPL, including continuing the Decontamination and Decommissioning (D&D) and ongoing care taking for the tritium systems and other radioactive components at TFTR, site-wide waste management activities, and General Plant Projects (GPP) and General Purpose Equipment (GPE). GPP and GPE funding supports essential facility renovations and other necessary capital alterations and additions to buildings and utility systems.

The principal objective of the Facility Operations subprogram is to operate the facilities in a safe, environmentally sound manner for the number of weeks shown in the table below. Operating in this manner will maximize the quantity and quality of data collected at the major fusion research facilities while building a culture of operational excellence and complying with all applicable safety and environmental requirements. Funding included for these facilities provides a modest reduction in operating time relative to FY 2001.

The table below summarizes the scheduled weeks of operations for DIII-D, C-Mod, and NSTX.

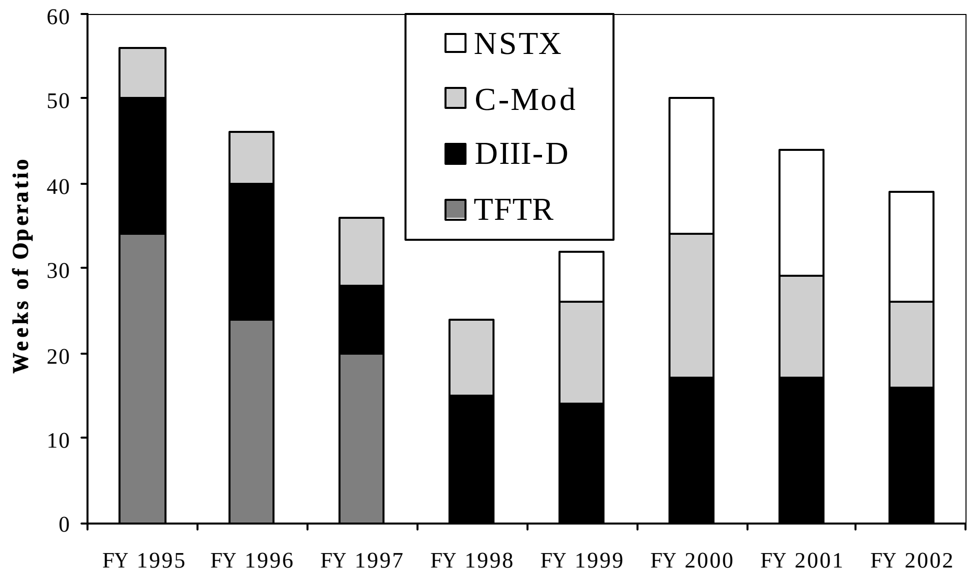
Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence, and relevance; quality; and safety and health.

Weeks of Fusion Facility Operation

(Weeks of Operations)

	FY 2000	FY 2001	FY 2002
DIII-D*	17	17	14
Alcator C-Mod	17	12	8
NSTX	16	15	11

* The number of weeks is calculated on the basis of the continuing availability of electrical power at affordable prices, an assumption that is now questionable in California.



Recent operating history of major fusion experimental facilities

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
TFTR	12,969	19,031	18,000	-1,031	-5.4%
DIII-D	30,523	29,249	26,706	-2,543	-8.7%
Alcator C-Mod	10,657	10,636	9,600	-1,036	-9.7%
NSTX	15,161	14,366	13,200	-1,166	-8.1%
General Plant Projects/Other	1,412	1,464	1,464	0	0.0%
Waste Management	2,984	3,150	3,024	-126	-4.0%
Total, Facility Operations	73,706	77,896	71,994	-5,902	-7.6%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
TFTR	**12,969**	**19,031**	**18,000**

In FY 2002, **performance will be measured by** successfully completing in a safe manner TFTR D&D ($14,500,000). This activity will provide for the removal and disposal of the tokamak and remaining radioactive components from the test cell and the basement. In addition, during the D&D, $3,500,000 is necessary to maintain and keep the facility safe. The original plan to provide a total of $21,000,000 in FY 2002 has been modified, based on recent project reviews, to defer $3,000,000 of management reserve expenditures into FY 2003 with the expectation that the project will be completed in FY 2002 without the need to spend the $3,000,000.

	FY 2000	FY 2001	FY 2002
DIII-D	**30,523**	**29,249**	**26,706**

Provide support for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems, such as the Electron Cyclotron Heating (ECH) systems. In FY 2002, these funds support 14 weeks of plasma operation (dependent upon electrical power availability in California).

	FY 2000	FY 2001	FY 2002
Alcator C-Mod	**10,657**	**10,636**	**9,600**

Provide support for operation, maintenance, major inspection of the fusion device, and minor machine improvements. In FY 2002, these funds support 8 weeks of plasma operation. Fabrication of a plasma heating and current drive system for Alcator C-Mod will be continued in FY 2002 and the system will be operational in 2003. This enhancement is a Major Item of Equipment with a TEC of $5,200,000 and a FY 2002 request of $1,167,000.

	FY 2000	FY 2001	FY 2002
NSTX	**15,161**	**14,366**	**13,200**
▪ **NSTX**	**12,661**	**14,366**	**13,200**

Provide support for operation, maintenance, and improvement of the NSTX facility and installation of planned diagnostic upgrades. In FY 2002, these funds support 11 weeks of plasma operation.

	FY 2000	FY 2001	FY 2002
▪ **NSTX Neutral Beam**	**2,500**	**0**	**0**

The NSTX neutral beam modification was completed in FY 2000 and was integrated into the NSTX research facility for use in FY 2001 research programs.

	FY 2000	FY 2001	FY 2002
General Plant Projects/General Purpose Equipment	**1,412**	**1,464**	**1,464**

These funds provide primarily for general infrastructure repairs and upgrades for the PPPL site based upon quantitative analysis of safety requirements, equipment reliability and research needs.

	FY 2000	FY 2001	FY 2002
Waste Management	**2,984**	**3,150**	**3,024**

These funds support necessary waste management activities at the PPPL site.

	FY 2000	FY 2001	FY 2002
Total, Facility Operations	**73,706**	**77,896**	**71,994**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
TFTR	
▪ The management reserve is reduced, increasing the risk that completion of the work will be deferred until FY 2003. The hope is that the work will be completed in FY 2002..	-1,031
DIII-D	
▪ Funding for DIII-D operations is decreased to provide funding to meet programmatic responsibilities to clean up the TSTA facility, and for other programmatic needs.	-2,543
Alcator C-Mod	
▪ Funding for Alcator C-Mod operations is decreased to provide funding to meet programmatic responsibilities to clean up the TSTA facility, and for other programmatic needs	-1,036
NSTX	
▪ Funding for NSTX operations is decreased to provide funding to meet programmatic responsibilities to clean up the TSTA facility, and for other programmatic needs.	-1,166
Waste Management	
▪ Funding for Waste Management is decreased to provide for other programmatic needs.	-126
Total Funding Change, Facility Operations	-5,902

Enabling R&D

Mission Supporting Goals and Objectives

The Enabling Research and Development subprogram provides for sustained progress toward fusion research goals through continuing innovation of technologies used in experimental fusion research facilities. The Enabling R&D subprogram provides such innovations for both magnetic and inertial fusion research facilities. This subprogram is divided into two elements: Engineering Research and Materials Research.

The Engineering Research element has completed a major restructuring following the U.S. withdrawal from the International Thermonuclear Experimental Reactor (ITER) project. The scope of activities has been substantially broadened to address more fully the diversity of domestic interests in enabling R&D for both magnetic and inertial fusion energy systems. These activities now focus on critical technology needs for enabling U.S. plasma experiments to achieve their full performance capability. Also, international technology collaborations allow the U.S. to access plasma experimental conditions not available domestically. These activities also include investigation of the scientific foundations of innovative technology concepts for future experiments. Another activity is advanced design of the most scientifically challenging systems for next-step fusion research facilities, i.e. facilities that may be needed in the immediate future. Also included are analysis and studies of critical scientific and technological issues, the results of which will provide guidance for optimizing future experimental approaches and for understanding the implications of fusion research on applications to fusion energy.

The Materials Research element continues to focus on the key science issues of materials for practical and environmentally attractive uses in fusion research and facilities while taking steps to implement the FESAC recommendations of 1998 that fusion materials research become more strongly oriented toward modeling and theory activities. This has made this element more effective at using and leveraging the substantial work on nanosystems and computational materials science being funded elsewhere, as well as more capable of contributing to broader materials research in niche areas of materials science. In addition, materials research of interest to both magnetic and inertial fusion energy systems has now been included in this element.

Management of the diverse and distributed collection of fusion enabling R&D activities is being accomplished through a Virtual Laboratory for Technology, with community-based coordination and communication of plans, progress, and results.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence, and relevance; quality; and safety and health.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Engineering Research	27,176	26,723	26,461	-262	-1.0%
Materials Research	7,052	6,664	6,600	-64	-1.0%
SBIR/STTR	0	898	0	-898	-100.0%
Total, Enabling R&D	34,228	34,285	33,061	-1,224	-3.6%

Detailed Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
Engineering Research	**27,176**	**26,723**	**26,461**
▪ **Plasma Technology**	**12,124**	**11,613**	**10,930**

Plasma Technology efforts will be focused on critical needs of domestic plasma experiments and on the scientific foundations of innovative technology concepts for use in future magnetic and inertial fusion experiments. Nearer-term experiment support efforts will be oriented toward plasma facing components and plasma heating and fueling technologies. A feasibility assessment for deploying a first-generation liquid metal system that interacts with the plasma to permit direct control of plasma particle densities and temperatures in NSTX will be completed. Development will continue to ensure the needed robustness of the current 1.0 million watt microwave generator that will efficiently heat plasmas to temperatures needed to verify computer models; development will also address critical issues on an advanced 1.5 million watt generator. Funds will be provided to continue superconducting magnet research and innovative technology research in the area of plasma-surface interaction sciences that will enable fusion experimental facilities to achieve their major scientific research goals and full performance potential.

	FY 2000	FY 2001	FY 2002
▪ **Fusion Technology**	**9,574**	**9,800**	**10,500**

Fusion Technology efforts will be focused on technology innovations and model improvements needed to resolve critical issues faced by both inertial and magnetic fusion concepts. These issues include identifying innovative approaches to fusion reaction chamber design as well as tritium and safety-related aspects of these chambers. In FY 2002, funding for Fusion Technologies is increased to permit the tritium inventory reduction needed to place this facility in a stabilized condition in preparation for transfer of this excess facility to EM. Funding for TSTA is increased by $1,137,000 to $3,300,000. In FY 2002, **performance will be measured by** completing a preliminary technical assessment of technology issues and approaches for inertial fusion energy concepts in the areas of the high energy density plasma chambers, target fabrication and tracking, and target-chamber interfaces, including studies of safety issues. Funds will continue to be provided for the US/Japan collaboration on innovative chamber technology research at a level that allows the US to more fully exploit investments made to enable this collaboration in tritium, coolant flow, and heat transfer research facilities.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
▪ **Advanced Design**	**5,478**	**5,310**	**5,031**

Funding for this element will focus on design studies of systems for next-step plasma science experiment options. Initial systems science studies to assess both the research needs underlying achievement of the safety, economics, and environmental characteristics and the prospects of possible inertial fusion energy systems will be conducted in an iterative fashion with the experimental community.

Materials Research	**7,052**	**6,664**	**6,600**

Materials Research remains a key element of establishing the scientific foundations for safe and environmentally attractive uses of fusion. Through a wide variety of modeling and experiment activities aimed at the science of materials behavior in fusion environments, research on candidate materials for the structural elements of fusion chambers will continue. Priorities for this work are based on the innovative approaches to evaluating materials and improved modeling of materials behavior that were adopted as a result of recommendations from the FESAC review completed in1998. Research includes materials and conditions relevant to inertial fusion systems as well as magnetic systems. Investigations will be conducted on the limits of strength and toughness of materials based on dislocation propagation and interactions with crystalline matrix obstacles, and the changes to thermal and electrical conductivity in materials based on electron and photon transport and scattering at the atomic level.

SBIR/STTR	**0**	**898**	**0**

In FY 2000, $887,000 and $53,000 were transferred to the SBIR and STTR programs, respectively. The FY 2001 amount is the estimated requirement for the continuation of these programs. Beginning in FY 2002, all SBIR/STTR requirements will be funded in the Science subprogram.

Total, Enabling R&D	**34,228**	**34,285**	**33,061**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Engineering Research	
▪ Funding for plasma technologies is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-683
▪ Funding for TSTA is increased by $1,137,000 to $3,300,000 to permit activities to clean up the facility prior to turning it over to the Office of Environmental Management for Decontamination and Decommissioning. Funding for all other fusion technologies activities is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	+700
▪ Funding Advanced Design and Analysis is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-279
Total, Engineering Research	-262
Materials Research	
▪ The level of material research effort will be slightly reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility.	-64
SBIR/STTR	
▪ In the past, funding requirements for SBIR/STTR had been split between the Science and Enabling R&D subprograms. Beginning in FY 2002, all SBIR/STTR requirements will be funded in the Science subprogram.	-898
Total Funding Change, Enabling R&D	-1,224

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects	1,062	1,369	1,369	0	0.0%
Capital Equipment	16,114	7,243	4,318	-2,925	-40.4%
Total, Capital Operating Expenses	17,176	8,612	5,687	-2,925	-34.0%

Major Items of Equipment *(TEC $2 million or greater)*

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2000	FY 2001	FY 2002	Accept-ance Date
DIII-D Upgrade	27,203	21,460	4,900	843	0	FY 2001
NSTX – Neutral Beam	5,950	3,450	2,500	0	0	FY 2000
Alcator C-Mod LH Modification	5,200 [a]	0	1,133	1,833	1,167	FY 2003
Total, Major Items of Equipment		24,910	8,533	2,676	1,167	

[a] Includes increase in TEC of $1,067,000 to be provided in FY 2003, and six-month delay based upon results of completion of the design. Such a change would normally be accommodated by contingency funds, but for this relatively modest MIE, such funds were not included in the original cost estimate.

Safeguards and Security

Program Mission

The mission of the Office of Science (SC) Safeguards and Security program is to ensure appropriate levels of protection against: unauthorized access, theft, diversion, loss of custody, or destruction of Department of Energy (DOE) assets and hostile acts that may cause adverse impacts on fundamental science, national security or the health and safety of DOE and contractor employees, the public or the environment. Each site has a tailored protection program as analyzed and defined in each site's Security Plan (SP) or other appropriate plan.

Security at SC sites is primarily focused on the protection of the DOE personnel, facilities, and equipment. Security interests include multi-million dollar, world-class research and development equipment and facilities, technical and administrative buildings, warehouses, and maintenance facilities. While some sites perform national security activities, the nature of the work typically involves limited issuance of individual security clearances and minimal classified information or material. Very small amounts of nuclear material are stored at a majority of sites. Particular emphasis is placed upon cyber security to provide hardware, software, communication, and data protection.

Protection policies, procedures, and operations at SC sites are equivalent to or greater than the level of security at university research facilities or private sector/commercial industrial facilities. The majority of these sites are located in a college campus-style setting with security assuming a low visibility posture. Site protective forces are generally unarmed and consist of less than 20 personnel. These security officers are utilized in stationary guard posts and mobile security patrols within the confines of the sites. Use is made of security fences, barriers, lighting, intrusion detection systems, and closed-circuit television.

Program Goal

The goal of the Office of Science Safeguards and Security program is to provide appropriate protection of research facilities and property, personnel, information and nuclear materials in a technically sound and cost-effective manner.

Program Objectives

- To provide laboratories and research facilities with adequate safeguards and security measures.
- To provide levels of protection in a tailored manner in accordance with potential risks.
- To correct any identified safeguards and security inadequacies.
- To anticipate evolving threats and provide protective measures.
- To maintain a balance between security and SC research mission.

The following is a brief description of the type of activities performed:

Physical Protection Protective Forces

The Physical Protection Protective Forces activity provides for security guards, management, and or supervision, training and equipment needed for effective performance of protection tasks during normal and emergency conditions.

Physical Security Protective Systems

The Physical Security Protective Systems activity provides for equipment to protect vital security interests and government property per the local threat. Equipment and hardware includes fences, barriers, lighting, sensors, entry control devices, etc. This hardware and equipment is generally operated and used to support the protective guard mission as well.

Information Security

The Information Security activity ensures that materials and documents, that may contain sensitive or classified information, are accurately and consistently identified, properly reviewed for content, appropriately marked and protected from unauthorized disclosure, and ultimately destroyed in an appropriate manner.

Cyber Security

The Cyber Security activity ensures that sensitive and classified information that is electronically processed or transmitted is properly identified, protected, and tested and that all electronic systems have an appropriate level of infrastructure reliability and integrity.

Personnel Security

The Personnel Security activity includes clearance program, security education and awareness for employees, and visitor control. This is accomplished through initial and termination briefings, re-orientations, computer based training, special workshops, publications, signs, and posters.

Material Control and Accountability

The Material Control and Accountability activity provides for the control and accountability of special nuclear materials, including training and development for assessing the amounts of material involved in packaged items, process systems and wastes. Additionally, this activity documents that a theft, diversion or operational loss of special nuclear material has not occurred. Also included is on-site and off-site transport of special nuclear materials in accordance with mission, environmental and safety requirements.

Program Management

The Program Management activity includes the development and updating of security plans, assessments and approvals to determine if assets are at risk, and policy oversight. Also encompassed are contractor management and administration, planning and integration of security activities into facility operations.

Significant Accomplishments and Program Shifts

Beginning in FY 2001, Safeguards and Security activities are direct funded in the "Science" appropriation. Previously these activities were generally funded as a site overhead function. For FY 2001, the Department submitted an amended budget request to consolidate and direct fund safeguards and security in the Office of Security and Emergency Operations. Congress directed that the direct responsibility for safeguards and security must be united and integrated with the responsibility of line operations. This FY 2002 request directly funds safeguards and security activities in accordance with congressional guidance. Increased program emphasis is being provided to cyber security commensurate with increased threats and technology advances.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Science Safeguards and Security					
Protective Forces	22,609	22,211	-60	22,151	26,540
Security Systems	3,725	4,786	-13	4,773	6,956
Transportation	0	262	-262 [a]	0	0
Information Security	696	694	-3	691	940
Cyber Security	5,523	6,450	-16	6,434	10,364
Personnel Security	1,733	1,705	-4	1,701	2,202
Material Control and Accountability	5,083	2,307	+255	2,562	3,169
Program Management	3,200	3,265	-8	3,257	5,241
Program Direction	0	13,260	-13,260	0	0
Subtotal, Science Safeguards and Security	42,569	54,940	-13,371	41,569	55,412
Less Security Charge for Reimbursable Work	-5,266	-5,122	0	-5,122	-4,912
Subtotal, Science Safeguards and Security	37,303	49,818	-13,371	36,447	50,500
Omnibus Rescission	0	-110	110	0	0
Total, Science Safeguards and Security	37,303	49,708	-13,261 [b]	36,447	50,500

Public Law Authorization:
Public Law 95-91, “Department of Energy Organization Act”
Public Law 103-62, “Government Performance and Results Act of 1993”

[a] Funding in the amount of $262,000 is transferred from Transportation to Material Control and Accountability.

[b] Excludes $13,261,000 in FY 2001 transferred to other DOE programs in FY 2002 for program direction related safeguards and security activities.

Funding By Site

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Chicago Operations Office					
Ames Laboratory	254	264	397	+133	+50.4%
Argonne National Laboratory	10,678	11,807	15,355	+3,548	+30.0%
Brookhaven National Laboratory	9,585	9,428	10,986	+1,558	+16.5%
Fermi National Accelerator Laboratory	2,294	2,490	2,765	+275	+11.0%
Princeton Plasma Physics Laboratory	1,680	1,735	1,829	+94	+5.4%
Total, Chicago Operations Office	24,491	25,724	31,332	+5,608	+21.8%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	3,612	3,492	4,709	+1,217	+34.9%
Stanford Linear Accelerator Center	1,774	1,814	2,152	+338	+18.6%
Oakland Operations Office	2,478	0	0	0	0.0%
Total, Oakland Operations Office	7,864	5,306	6,861	+1,555	+29.3%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education	764	885	1,248	+363	+41.0%
Oak Ridge National Laboratory	8,970	9,162	15,024	+5,862	+64.0%
Thomas Jefferson National Accelerator Facility	480	492	947	+455	+92.5%
Total, Oak Ridge Operations Office	10,214	10,539	17,219	+6,680	+63.4%
Total, Science Safeguards and Security	42,569	41,569	55,412	+13,843	+33.3%
Less Security Charge for Reimbursable Work	-5,266	-5,122	-4,912	+210	+4.1%
Total, Science Safeguards and Security	37,303	36,447	50,500	+14,053	+38.6%

Site Description

Safeguards and Security activities are conducted to meet the requirements of the following program elements: Physical Protection Protective Forces, Physical Security Protective Systems, Information Security, Cyber Security, Personnel Security, Material Control and Accountability, and Program Management. A summary level description of each activity is provided in the preceding Program Mission narrative. These activities ensure adequate protection for DOE security interests.

The attainment of the Safeguards and Security program goals and objectives are measured by progress made towards established performance measures. The technical excellence of the field security program is continually re-evaluated through field and Headquarters reviews. **Performance will be measured** at all sites by accomplishing the following:

- SC will prevent 99% of all unauthorized intrusions to systems that process sensitive unclassified information.
- Physical Security Systems will prevent all unauthorized access to security areas at SC labs.
- Protective Forces will prevent all unauthorized access to security areas at SC labs.

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Ames Laboratory	**254**	**264**	**397**

The Ames Laboratory Safeguards and Security program coordinates planning, policy, implementation and oversight in the areas of physical security, protective forces, personnel security, material control and accountability and cyber security. Access control management, maintaining uninterrupted power supply systems, and investigating and reporting incidents are also critical ongoing efforts. A protective force to protect Ames Laboratory and DOE assets is maintained. Ames actively carries out ongoing efforts to install and maintain cyber security software, hardware, and system configurations within the Ames Laboratory network, that is receiving increased attention (+110,000). The nuclear materials control program prevents or deters the loss or misuse of nuclear materials. Reimbursable work is included in the numbers above. The amount for FY 2002 is $34,000.

Argonne National Laboratory	**10,678**	**11,807**	**15,355**

The Argonne National Laboratory Safeguards and Security program provides protection of nuclear materials, classified matter, government property, and other vital assets from unauthorized access, theft, diversion, sabotage, espionage, or other hostile acts that may cause risks to national security or the health and safety of DOE and contractor employees, the public, or the environment. Program activities include physical security (+795,000), material control and accountability, operational security, transportation safeguards, information and cyber security (that is receiving increased emphasis) (+856,000), physical security, and personnel security. In addition, a protective force is maintained. These activities ensure that the facility, personnel, and assets remain safe from potential threats. Reimbursable work is included in the numbers above. The amount for FY 2002 is $840,000.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Brookhaven National Laboratory	**9,585**	**9,428**	**10,986**

Brookhaven National Laboratory (BNL) Safeguards and Security program activities are focused on information security, cyber security, physical security, and material control and accountability. Information security pertains primarily to information protection and declassification/classification activities. Cyber security efforts are focused on unclassified and classified computer security and cyber infrastructure, that is receiving increased attention (+174,000). BNL operates a transportation division to move special nuclear materials around the site. The personnel security program focuses on badging and clearance investigations. Material control and accountability efforts focus on accurately accounting for and protecting the sites special nuclear materials. In addition, protective forces (+1,018,000) are employed to ensure the protection of the Laboratory and national assets. Reimbursable work is included in the numbers above. The amount for FY 2002 is $806,000.

Fermi National Accelerator Laboratory	**2,294**	**2,490**	**2,765**

Fermi National Accelerator Laboratory Safeguards and Security program efforts are directed at maintaining protective force staffing and operations to protect personnel and the facility as well as continue cyber security, physical security, and a material control and accountability program to accurately account for and protect the facilities special nuclear materials. Both cyber security (+269,000) and protective force (+5,000) are receiving increased attention.

Lawrence Berkeley National Laboratory	**3,612**	**3,492**	**4,709**

The Lawrence Berkeley National Laboratory Safeguards and Security program provides physical protection of personnel and laboratory facilities. This is accomplished with protective forces, cyber security, personnel security and material control and accountability. Access controls utilizing physical security upgrades (+464,000), cyber security (+434,000) and protective forces are receiving increased attention. Reimbursable work is included in the numbers above. The amount for FY 2002 is $830,000.

Oakland Operations Office	**2,478**	**0**	**0**

This activity provides for direct funded material control and accountability functions in FY 2000 only. Funding responsibility transferred to NNSA in FY 2001; in accord with DOE realignment of responsibilities.

Oak Ridge Institute for Science and Education............	**764**	**885**	**1,248**

The Oak Ridge Institute for Science and Education (ORISE) Safeguards and Security program provides physical protection/protective force services by employing unarmed security officers. The facilities are designated as property protection areas for the purpose of protecting government owned assets. In addition to the government owned facilities and personal property, ORISE possesses small quantities of nuclear materials that must be protected. The program includes information security, personnel security, protective forces, physical security, and cyber security. Cyber security (+188,000) and protective forces (+75,000) are receiving increased attention. Reimbursable work is included in the numbers above. The amount for FY 2002 is $319,000.

Oak Ridge National Laboratory	**8,970**	**9,162**	**15,024**

The Oak Ridge National Laboratory (ORNL) Safeguards and Security program includes protective forces, physical security systems, information security, cyber security, personnel security, material

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

control and accountability, and program management. Program planning functions at the Laboratory provide for short and long range strategic planning, and special safeguards plans associated with both day-to-day protection of site-wide security interests and preparation for contingency operations. Additionally, ORNL is responsible for provision of overall Laboratory policy direction and oversight in the security arena, for conducting recurring programmatic self-assessments; for assuring a viable ORNL Foreign Ownership, Control or Influence (FOCI) program is in place; and for identifying, or tracking, and obtaining closure on findings or deficiencies noted during inspections, surveys, or assessments of safeguards and security programs. Increased attention is being given to protective forces (+2,372,000), security systems (+712,000), and cyber security (+1,413,000). Reimbursable work is included in the numbers above. The amount for FY 2002 is $1,945,000.

Princeton Plasma Physics Laboratory	**1,680**	**1,735**	**1,829**

The Princeton Plasma Physics Laboratory Safeguards and Security program provides for protection of nuclear materials, government property, and other vital assets from unauthorized access, theft, diversion, sabotage, or other hostile acts. These activities result in reduced risk to national security and the health and safety of DOE and contractor employees, the public, and the environment. Efforts are primarily focused on cyber security (+61,000) and protective forces (+30,000). Reimbursable work is included in the numbers above. The amount for FY 2002 is $54,000.

Stanford Linear Accelerator Center................................	**1,774**	**1,814**	**2,152**

The Stanford Linear Accelerator Center Safeguards and Security program focuses on reducing the threat to DOE national facilities and assets. The program consists primarily of physical protection protective forces and cyber security program elements. Increased attention is being given to cyber security (+271,000). Reimbursable work is included in the numbers above. The amount for FY 2002 is $84,000.

Thomas Jefferson National Accelerator Facility	**480**	**492**	**947**

Thomas Jefferson National Accelerator Facility has a guard force which provides 24-hour services for the accelerator site and after-hours property protection security for the entire site. There is increased funding for electronic card access. Increased attention has been given to the Security Program Management (+144,000). Additionally, the security program provides for cyber security protection (that is receiving increased attention) (+154,000), and recording of after-hours personnel accessing the site (+115,000).

Subtotal, Science Safeguards and Security.....................	**42,569**	**41,569**	**55,412**
Less Security Charge for Reimbursable Work	**-5,266**	**-5,122**	**-4,912**
Total, Science Safeguards and Security	**37,303**	**36,447**	**50,500**

Detailed Funding Profile

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Ames Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	94	98	111	+13	+13.3%
Training	1	1	1	0	0.0%
Other	28	28	28	0	0.0%
Total, Protective Forces	123	127	140	+13	+10.2%
Security Systems					
Physical Security	23	24	26	+2	+8.3%
Cyber Security					
Unclassified Computer Security	6	6	129	+123	+2,050.0%
Communications Security	18	19	6	-13	-68.4%
Total, Cyber Security	24	25	135	+110	+440.0%
Personnel Security					
Clearance Program and Visit Control	36	38	42	+4	+10.5%
Material Control and Accountability					
Material Control and Accounting	6	6	6	0	0.0%
Program Management					
Planning	11	12	12	0	0.0%
Professional Training and Development	7	7	7	0	0.0%
Policy Oversight and Administration	24	25	29	+4	+16.0%
Total, Program Management	42	44	48	+4	+9.1%
Total, Ames Laboratory	254	264	397	+133	+50.4%
Argonne National Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	5,321	5,066	5,631	+565	+11.2%
Training	50	50	50	0	0.0%
Other	827	825	827	+2	+0.2%
Total, Protective Forces	6,198	5,941	6,508	+567	+9.5%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Security Systems					
Physical Security	554	1,921	2,716	+795	+41.4%
Explosive Detection	65	65	65	0	0.0%
Escorts	4	4	4	0	0.0%
Total, Security Systems	623	1,990	2,785	+795	+39.9%
Information Security					
Information Protection	164	163	182	+19	+11.7%
Declassification/Classification	44	44	56	+12	+27.3%
Information Assurance	16	16	16	0	0.0%
Technical Surveillance Countermeasures	21	21	16	-5	-23.8%
Operations Security	93	93	88	-5	-5.4%
Total, Information Security	338	337	358	+21	+6.2%
Cyber Security					
Unclassified Computer Security	309	316	838	+522	+165.2%
Classified Computer Security	29	37	70	+33	+89.2%
Communications Security	0	6	6	0	0.0%
TEMPEST	1	4	8	+4	+100.0%
Cyber Infrastructure	697	701	998	+297	+42.4%
Total, Cyber Security	1,036	1,064	1,920	+856	+80.5%
Personnel Security					
Clearance Program and Visit Control	516	514	548	+34	+6.6%
Security Awareness Program	69	69	69	0	0.0%
Total, Personnel Security	585	583	617	+34	+5.8%
Material Control and Accountability					
Material Control and Accounting	1,159	1,155	1,234	+79	+6.8%
Transportation	124	124	124	0	0.0%
Total, Material Control and Accountability	1,283	1,279	1,358	+79	+6.2%
Program Management					
Planning	158	158	737	+579	+366.5%
Professional Training and Development	90	90	90	0	0.0%
Policy Oversight and Administration	367	365	982	+617	+169.0%
Total, Program Management	615	613	1,809	+1,196	+195.1%
Total, Argonne National Laboratory	10,678	11,807	15,355	+3,548	+30.0%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Brookhaven National Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	5,225	4,811	5,667	+856	+17.8%
Training	112	105	109	+4	+3.8%
Other	336	315	473	+158	+50.2%
Total, Protective Forces	5,673	5,231	6,249	+1,018	+19.5%
Security Systems					
Physical Security	1,323	943	1,052	+109	+11.6%
Explosive Detection	19	20	0	-20	-100.0%
Escorts	19	20	0	-20	-100.0%
Total, Security Systems	1,361	983	1,052	+69	+7.0%
Information Security					
Information Protection	116	98	115	+17	+17.3%
Declassification/Classification	17	14	15	+1	+7.1%
Information Assurance	8	7	37	+30	+428.6%
Technical Surveillance Countermeasures	8	7	0	-7	-100.0%
Operations Security	17	14	0	-14	-100.0%
Total, Information Security	166	140	167	+27	+19.3%
Cyber Security					
Unclassified Computer Security	520	1,273	1,438	+165	+13.0%
Classified Computer Security	227	205	214	+9	+4.4%
Communications Security	14	13	13	0	0.0%
TEMPEST	6	5	5	0	0.0%
Cyber Infrastructure	9	8	8	0	0.0%
Total, Cyber Security	776	1,504	1,678	+174	+11.6%
Personnel Security					
Clearance Program and Visit Control	20	20	22	+2	+10.0%
Security Awareness Program	2	2	2	0	0.0%
Total, Personnel Security	22	22	24	+2	+9.1%
Material Control and Accountability					
Material Control and Accounting	439	367	502	+135	+36.8%
Transportation	132	138	138	0	0.0%
Total, Material Control and Accountability	571	505	640	+135	+26.7%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Program Management					
Planning	305	313	328	+15	+4.8%
Professional Training and Development	102	105	109	+4	+3.8%
Policy Oversight and Administration	609	625	739	+114	+18.2%
Total, Program Management	1,016	1,043	1,176	+133	+12.7%
Total, Brookhaven National Laboratory	9,585	9,428	10,986	+1,558	+16.5%
Fermi National Accelerator Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	1,414	1,468	1,355	-113	-7.7%
Training	64	67	76	+9	+13.4%
Other	104	108	217	+109	+100.9%
Total, Protective Forces	1,582	1,643	1,648	+5	+0.3%
Security Systems					
Physical Security	257	266	267	+1	+0.4%
Cyber Security					
Unclassified Computer Security	313	434	703	+269	+62.0%
Material Control and Accountability					
Material Control and Accounting	35	36	36	0	0.0%
Program Management					
Planning	29	30	30	0	0.0%
Professional Training and Development	30	30	42	+12	+40.0%
Policy Oversight and Administration	48	51	39	-12	-23.5%
Total, Program Management	107	111	111	0	0.0%
Total, Fermi National Accelerator Laboratory	2,294	2,490	2,765	+275	+11.0%
Lawrence Berkeley National Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	791	802	1,000	+198	+24.7%
Other	121	123	125	+2	+1.6%
Total, Protective Forces	912	925	1,125	+200	+21.6%
Security Systems					
Physical Security	868	896	1,360	+464	+51.8%
Cyber Security					
Unclassified Computer Security	1,299	1,122	1,556	+434	+38.7%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Personnel Security					
Clearance Program	106	109	134	+25	+22.9%
Security Awareness Program	12	12	13	+1	+8.3%
Total, Personnel Security	118	121	147	+26	+21.5%
Material Control and Accountability					
Material Control and Accounting	64	66	80	+14	+21.2%
Program Management					
Planning	105	109	113	+4	+3.7%
Professional Training and Development	18	18	19	+1	+5.6%
Policy Oversight and Administration	228	235	309	+74	+31.5%
Total, Program Management	351	362	441	+79	+21.8%
Total, Lawrence Berkeley National Laboratory	3,612	3,492	4,709	+1,217	+34.9%
Oakland Operations Office					
Material Control and Accountability					
Material Control and Accounting	2,478	0	0	0	0.0%
Oak Ridge Institute for Science and Education					
Protective Forces					
Salaries, Wages, and Benefits	100	108	181	+73	+67.6%
Training	4	4	4	0	0.0%
Other	60	70	72	+2	+2.9%
Total, Protective Forces	164	182	257	+75	+41.2%
Security Systems					
Physical Security	69	73	98	+25	+34.2%
Information Security					
Information Protection	30	34	61	+27	+79.4%
Declassification/Classification	10	12	12	0	0.0%
Technical Surveillance Countermeasures	8	6	6	0	0.0%
Operations Security	16	29	30	+1	+3.4%
Total, Information Security	64	81	109	+28	+34.6%
Cyber Security					
Unclassified Computer Security	140	189	373	+184	+97.4%
Classified Computer Security	50	117	119	+2	+1.7%
Communications Security	15	35	36	+1	+2.9%
TEMPEST	10	12	12	0	0.0%
Cyber Infrastructure	50	59	60	+1	+1.7%
Total, Cyber Security	265	412	600	+188	+45.6%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Personnel Security					
Clearance Program and Visit Control	98	113	159	+46	+40.7%
Security Awareness Program	104	24	25	+1	+4.2%
Total, Personnel Security	202	137	184	+47	+34.3%
Total, Oak Ridge Institute for Science and Education	764	885	1,248	+363	+41.0%
Oak Ridge National Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	3,365	3,684	5,841	+2,157	+58.6%
Training	471	489	152	-337	-68.9%
Other	1,432	1,171	1,723	+552	+47.1%
Total, Protective Forces	5,268	5,344	7,716	+2,372	+44.4%
Security Systems					
Physical Security	436	451	1,185	+734	+162.7%
Escorts	21	22	0	-22	-100.0%
Total, Security Systems	457	473	1,185	+712	+150.5%
Information Security					
Information Protection	59	62	185	+123	+198.4%
Declassification/Classification	0	0	31	+31	+100.0%
Technical Surveillance Countermeasures	35	36	30	-6	-16.7%
Operations Security	34	35	60	+25	+71.4%
Total, Information Security	128	133	306	+173	+130.1%
Cyber Security					
Unclassified Computer Security	549	570	1,876	+1,306	+229.1%
Classified Computer Security	185	193	300	+107	+55.4%
Total, Cyber Security	734	763	2,176	+1,413	+185.2%
Personnel Security					
Clearance Program and Visit Control	743	772	1,135	+363	+47.0%
Security Awareness Program	27	28	53	+25	+89.3%
Total, Personnel Security	770	800	1,188	+388	+48.5%
Material Control and Accountability					
Material Control and Accounting	646	670	1,049	+379	+56.6%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Program Management					
Planning	758	762	1,001	+239	+31.4%
Professional Training and Development	0	0	47	+47	+100.0%
Policy Oversight and Administration	209	217	356	+139	+64.1%
Total, Program Management	967	979	1,404	+425	+43.4%
Total, Oak Ridge National Laboratory	8,970	9,162	15,024	+5,862	+64.0%
Princeton Plasma Physics Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	670	694	723	+29	+4.2%
Training	82	83	84	+1	+1.2%
Other	94	97	97	0	0.0%
Total, Protective Forces	846	874	904	+30	+3.4%
Security Systems					
Physical Security	62	63	58	-5	-7.9%
Escorts	5	5	10	+5	+100.0%
Total, Security Systems	67	68	68	0	0.0%
Cyber Security					
Unclassified Computer Security	665	688	749	+61	+8.9%
Program Management					
Planning	31	32	32	0	0.0%
Professional Training and Development	8	8	8	0	0.0%
Policy Oversight and Administration	63	65	68	+3	+4.6%
Total, Program Management	102	105	108	+3	+2.9%
Total, Princeton Plasma Physics Laboratory	1,680	1,735	1,829	+94	+5.4%
Stanford Linear Accelerator Center					
Protective Forces					
Salaries, Wages, and Benefits	220	227	229	+2	+0.9%
Other	1,243	1,265	1,330	+65	+5.1%
Total, Protective Forces	1,463	1,492	1,559	+67	+4.5%
Cyber Security					
Unclassified Computer Security	311	322	593	+271	+84.2%
Total, Stanford Linear Accelerator Center	1,774	1,814	2,152	+338	+18.6%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Thomas Jefferson National Accelerator Facility					
Protective Forces					
Salaries, Wages, and Benefits	336	346	387	+41	+11.8%
Other	44	46	47	+1	+2.2%
Total, Protective Forces	380	392	434	+42	+10.7%
Security Systems					
Physical Security	0	0	115	+115	+100.0%
Cyber Security					
Unclassified Computer Security	100	100	216	+116	+116.0%
Cyber Infrastructure	0	0	38	+38	+100.0%
Total, Cyber Security	100	100	254	+154	+154.0%
Program Management					
Policy Oversight and Administration	0	0	144	+144	+100.0%
Total, Thomas Jefferson National Accelerator Facility	480	492	947	+455	+92.5%
Subtotal, Science Safeguards and Security	42,569	41,569	55,412	+13,843	+33.3%
Less Security Charge for Reimbursable Work	-5,266	-5,122	-4,912	+210	+4.1%
Total, Science Safeguards and Security	37,303	36,447	50,500	+14,053	+38.6%

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Ames Laboratory	
▪ Increase mainly in cyber security.	+133
Argonne National Laboratory	
▪ Increases mainly in cyber security protection requirements (+856,000) and program management needs (+1,196,000). Oversight reviews identified significant vulnerabilities in the cyber security programs at Argonne National Laboratory that required enhanced protection measures. Also an increase in physical security for upgrades to aging systems at Argonne National Laboratory – West (+631,000).	+3,548
Brookhaven National Laboratory	
▪ Increases mainly in protective forces and cyber security protection requirements.	+1,558
Fermi National Accelerator Laboratory	
▪ Increase mainly in cyber security.	+275
Lawrence Berkeley National Laboratory	
▪ Increases mainly in physical security and cyber security	+1,217
Oakland Operations Office	
▪ No activities in FY 2001 or FY 2002; in accord with DOE realignment of responsibilities, transferred to NNSA.	0
Oak Ridge Institute for Science and Education	
▪ Minor changes in funding requirements.	+363
Oak Ridge National Laboratory	
▪ The increases are mainly in protective force services (+2,372,000), physical security system upgrades (+712,000) and cyber security (+1,413,000). Independent oversight inspectors identified vulnerabilities in the protection of sensitive unclassified information that required enhanced physical and cyber security protection.	+5,862
Princeton Plasma Physics Laboratory	
▪ Minor changes in funding requirements.	+94
Stanford Linear Accelerator Center	
▪ Minor changes in funding requirements.	+338

	FY 2002 vs. FY 2001 ($000)
Thomas Jefferson National Accelerator Facility	
▪ Increases mainly in Security Systems (+115,000), Cyber Security (+116,000), and Program Management (+144,000).	+455
Subtotal Funding Change, Science Safeguards and Security	+13,843
Less Security Charge for Reimbursable Work	+210
Total Funding Change, Science Safeguards and Security	+14,053

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects......................	0	1,369	2,000	+631	+46.1%
Total, Capital Operating Expenses	0	1,369	2,000	+631	+46.1%

Science Program Direction

Program Mission

Science Program Direction consists of three subprograms: Program Direction, Science Education, and Field Operations. Program Direction is the funding source for the Office of Science (SC) Federal staff that directs and administers a broad spectrum of scientific disciplines and provides technical and administrative support directly related to Science in Headquarters, the Chicago and Oak Ridge Operations Offices, and the Berkeley and Stanford Site Offices. Science Education sponsors programs that enable college and university students and faculty to take advantage of fellowship and research opportunities at the National Laboratories and user facilities, all designed to promote interest in science, math, engineering, and technology fields. Field Operations is the centralized funding source for the day-to-day operations, management and administrative functions, and the core Federal staff responsible for providing these services to the many different Departmental programs at the Chicago and Oak Ridge Operations Offices.

The **Program Direction** subprogram supports the overall direction of technical and scientific activities in the Basic Energy Sciences; Nuclear Physics; High Energy Physics; Biological and Environmental Research; Advanced Scientific Computing Research; and Fusion Energy Sciences programs and for managing laboratory infrastructure; security, environment, safety and health; administrative resources; policy; and planning. It provides funding for salaries and benefits, travel, support services, and other related expenses, including the Working Capital Fund.

The **Science Education** subprogram supports four educational human resource development programs. The Department is committed to math, science, engineering, and technology education programs to help provide a technically trained and diverse workforce for the Nation.

- The *Energy Research Undergraduate Laboratory Fellowship Program (ERULF)*, formerly known as the Laboratory Cooperative Program, is designed to provide educational training and research experiences at DOE laboratories for highly motivated undergraduate students. These opportunities complement academic programs and introduce students to the unique intellectual and physical resources present at the DOE laboratories. Appointments are available during the spring, summer, and fall terms. These research opportunities have also been extended in a pilot pre-service teacher program (PST) with the National Science Foundation, to undergraduate students who are preparing for careers in math, science, engineering or technology teaching.
- The *National Science BowlÒ Program* is a highly publicized academic competition among high school students who answer questions on scientific topics in astronomy, biology, chemistry, mathematics, physics, earth, computer and general science. This program was created to encourage high school students across the Nation to excel in math and science and to pursue careers in those fields. Since its inception, more than 60,000 high school students have participated in regional tournaments leading up to the national finals. This program provides the students, and teachers who have prepared them, a forum to receive national recognition for their talent and hard work.
- The *Albert Einstein Distinguished Educator Fellowship Program* supports outstanding science and mathematics teachers, who provide insight, extensive knowledge, and practical experience to the Legislative and Executive branches. This program is in compliance with the Albert Einstein Distinguished Educator Act of 1994 (signed into law in November 1994). The law gives DOE

responsibility for administering the program of distinguished educator fellowships for elementary and secondary school mathematics and science teachers.

- The *DOE Community College Institute (CCI) of Biotechnology, Environmental Science, and Computing* provides educational human resource development experiences at several DOE National Laboratories for highly motivated community college students. Each laboratory offers a 10-week summer experience for selected students from a regional consortium of community colleges collaborating with DOE and that laboratory. This experience is a collaboration among DOE National Laboratories and the American Association of Community Colleges.

The **Field Operations** subprogram enables the Chicago and Oak Ridge Operations Offices to manage programs, projects, laboratories, facilities, grants and contracts in support of science and technology, energy research, and environmental management activities under their purview. Field Operations provides the salaries and benefits, travel, and support services for the core administrative staff that perform managerial, business, fiduciary, contractual, and technical support functions and the day-to-day requirements of operating an office, i.e., rent, utilities, communications, information technology, office equipment, etc. The Oakland Operations Office, previously funded in this subprogram, is now funded in the National Nuclear Security Administration (NNSA) consistent with the field restructuring management reform initiated on October 1, 2000.

Program Goals

- Fund Federal staff and related expenses necessary to provide overall management direction of SC's scientific research and technology programs.
- Enable the Director of SC to serve as the Department's science advisor for formulation and implementation of basic and fundamental research policy.
- Sustain U.S. leadership in math, science, technology, and engineering by leveraging DOE resources in partnership with laboratories and facilities, other Federal agencies, academia and industry that contribute to the development of a diverse scientific and technical workforce for the 21st century.
- Provide management and administrative services that enable the Operations Offices to continue environmental cleanups; support the national laboratories and research facilities; institute environment, safety and health initiatives; maintain communications with stakeholders; create public and private partnerships; and take advantage of reindustrialization opportunities.

Program Objectives

Program Direction

- To develop, direct, and administer a complex and broadly diversified program of mission-oriented, basic and applied research and development designed to support new and improved energy, environmental, and health technologies.
- To manage the design, construction, and operation of forefront scientific research facilities for use by the Nation's scientific community, including the Spallation Neutron Source Project.
- To conduct independent technical assessments; peer reviews; and evaluate research proposals, programs, and projects.
- To enhance international collaboration and leverage the U.S. investment in research and development.

- To review, analyze, and where appropriate, champion the recommendations of SC's Federally-chartered advisory committees: the Fusion Energy Sciences Advisory Committee; High Energy Physics Advisory Panel; Department of Energy/National Science Foundation (DOE/NSF) Nuclear Science Advisory Committee; Basic Energy Sciences Advisory Committee; Biological and Environmental Research Advisory Committee; and the Advanced Scientific Computing Advisory Committee.

Science Education

- To provide opportunities and effective mechanisms for a diverse group of students and faculty to participate in research at the Department's laboratories related to SC's research programs, with a focus on undergraduates.
- To provide opportunities for participants to improve their communications skills through oral and written presentations of their research experience.

Field Operations

- To provide the day-to-day managerial, business, fiduciary, contractual, and technical foundation necessary to support programmatic missions in the areas of science and technology, energy research, and environmental management.
- To improve the operational efficiency through the development and implementation of integrated business management systems.
- To maintain the field infrastructure in an environment that is safe and hazard free.
- To improve communications with customers, stakeholders, and the public.

Significant Accomplishments and Program Shifts

SCIENCE ACCOMPLISHMENTS

Program Direction

- Achieved technical excellence in SC programs despite managing one of the largest, most diversified, and complex basic research portfolios in the Federal Government with a relatively small Federal and contractor support staff.
- Based on results of genomics and structural biology research, redirected resources to the "Genomes to Life" research program and implemented this research as recommended by the Biological and Environmental Research Advisory Committee, incorporating and expanding the Microbial Cell Project.
- Concluded the international agreement for U.S. participation in the Large Hadron Collider project. Signatories include the Secretary of Energy and the Director of the National Science Foundation. Execution of the project is ongoing.
- Transferred management responsibility for newly generated wastes at Ames Laboratory, Argonne National Laboratory/East, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Pacific Northwest National Laboratory, and Princeton Plasma Physics Laboratory from the Office of Environmental Management to SC.
- Planned and managed a complex, scientific R&D program to advance the knowledge base needed for an attractive fusion energy source.

- Refined the framework of appropriate international arrangements needed to carry out SC programs in a most cost-effective manner.
- Responded to recommendations from the Secretary of Energy Advisory Board and chartered a working group to prepare an Integrated Program Plan for fusion energy sciences. The Plan will be available early in 2001 and will describe the technical activities necessary for fusion program success and the relationships among these activities.
- Delivered the procurement module of the Information Management for Science (IMSC) system, a major business management corporate system within SC.
- Provided multiple information technology (IT) improvements as requested by the SC Headquarters business customers to assist them in carrying out the SC mission, e.g., refreshed 33 percent of laptops and customer workstations, made Internet Explorer 5.01 available, etc.
- Developed and initiated the implementation of SC's Cyber Security Plan.
- Implemented an "Information Architecture" process at the Chicago Operations Office, in accordance with the Information Technology Management Reform Act of 1996, that is compatible with the Information Architecture already implemented in SC Headquarters.
- Integrated direct safeguards and security responsibilities with line operations.
- Made organizational changes consistent with the principles established by Secretarial direction and subsequent management restructuring reforms unfolding as part of implementing the National Nuclear Security Administration (NNSA), including aligning the Berkeley and Stanford Site Offices under SC and relinquishing the Oakland Operations Office and the Y-12 Area Office to NNSA.

Science Education

- The Energy Research Undergraduate Laboratory Fellowship Program has implemented an innovative, interactive Internet system to receive and process hundreds of student applications for summer, fall, and spring semester research appointments at participating DOE laboratories. The automated system is virtually paperless and provides an excellent example of how the Internet can be used to streamline the operation of the Department's research participation programs. The on-line application system now has pre- and post-surveys that quantify student knowledge, performance and improvement, and allows SC to measure program effectiveness and track students in their career path.
- Through special recruitment efforts, the Energy Research Undergraduate Laboratory Fellowship Program has attracted a diverse group of students using the electronic application. Nearly 20 percent of those submitting applications were from under-represented ethnic groups. Approximately 40 percent of the applications were females, and more than 25 percent were from low-income families. In the summer of 1999, more than 400 appointments were made through the new application process and in the summer of 2000 more than 500 appointments were made through the new application process.
- Five additional regional competitions were held in conjunction with DOE's National Science BowlÒ. More than 9,000 high school students participated in the 53 regional science bowl tournaments.
- The Albert Einstein Distinguished Educator Fellowship Program placed 4 outstanding K-12 science, math, and technology teachers in Congressional offices and 1 at DOE, as directed by legislation. The

National Aeronautics and Space Administration and the National Science Foundation contributed funds to place 7 additional Einstein Fellows in those agencies.

- In FY 2000, SC piloted for the second year, its DOE Community College Institute of Biotechnology, Environmental Science, and Computing. In the summer of 2000, 118 community college students attended a 10-week scientific research experience at 6 DOE multipurpose laboratories. Almost 60 percent of the participating students came from under-represented groups in math, science, engineering, and technology; many were "non-traditional" students.
- The Community College Institute of Biotechnology, Environmental Science, and Computing received recognition as a semifinalist in the Harvard "Innovations in American Government Awards Program 2000." It was one of 96 semifinalists out of an original applicant pool of 1,300.

Field Operations

- Implemented the reorganization, resulting from the establishment of the NNSA required by the FY 2000 Defense Authorization and subsequent management reforms.
- In support of the Energy and Water Development Appropriations Act requirement under Section 310(A) and Section 311 of Public Law 106-60, Laboratory Funding Plans were prepared and overhead reviews of prime contractors were accomplished.
- Closed 400 contracts and grants.
- Improved contracting practices to become more competitive in the award process by holding contractors more accountable in the execution of Government contracts and moved to a performance-based contracting strategy.
- Successfully awarded the new contract to UT-Battelle, LLC, for the management of Oak Ridge National Laboratory (ORNL) at Oak Ridge.
- Awarded the new protective services contract to Wackenhut Services, Inc., which provides uniformed guards for the safeguards and security functions at the Y-12 Plant, Oak Ridge National Laboratory, East Tennessee Technology Park (ETTP), Federal Building, and Office of Scientific and Technical Information.

FACILITY ACCOMPLISHMENTS

Program Direction

- Completed the B-factory and its detector at the Stanford Linear Accelerator Center within scope and budget, and on schedule.
- Strengthened integrated safety and security management and infrastructure management at the national laboratories.
- Enhanced neutron science capability at the Los Alamos Neutron Science Center.
- Designed and continued construction of the Neutrinos at the Main Injector project at the Fermi National Accelerator Laboratory.
- Began construction of the Spallation Neutron Source at the Oak Ridge National Laboratory in FY 2000.

Field Operations

- Successfully tested, validated, and completed all critical computer systems at the Operations Offices and major laboratories for Y2K with no glitches.

PROGRAM SHIFTS

- In FY 1999, SC became the Lead Program Secretarial Office (LPSO) for Chicago, Oak Ridge, and Oakland Operations Offices. Then in October 2000, DOE changed the field structure and realigned work performed on behalf of NNSA under NNSA organizations.
- The FY 2001 Energy and Water Development Appropriations Act (H.R. 4733-23, Public Law 106-907), prohibited the Department from using appropriated funds to pay personnel engaged in concurrent service or duties in DOE and NNSA. As a result, the Oakland Operations Office is now part of NNSA and reports directly to the Deputy Administrator for Defense Programs (DP) instead of SC. The Oakland Operations Office Manager and staff, other than those who work on behalf of SC programs, are designated as NNSA employees.
- The Berkeley and Stanford Site Offices have oversight responsibilities for the Lawrence Berkeley National Laboratory and the Stanford Linear Accelerator Center, respectively, and report directly to the SC Director instead of the Oakland Operations Office Manager. The Y-12 Area Office reports to DP instead of to the Oak Ridge Operations Office Manager.
- A portion of SC's Program Direction budget, in the "Field Operations" subprogram, funded the administrative and management functions at Oakland. With the October 2000 realignment, this subprogram will not fund Oakland activities beginning in FY 2002.
- The FY 2001 Energy and Water Development Appropriations Act (H.R. 4733-23, Public Law 106-907) directed the Department to integrate safeguards and security responsibilities with line operations. Beginning in FY 2002, SC will support the safeguards and security federal staffing functions at the Oak Ridge Operations Office within the Program Direction subprogram.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Science Program Direction					
Program Direction	57,505 [a]	51,438	+9,642 [a]	61,080	72,525
Science Education	4,472 [b]	4,500	-40 [b]	4,460	5,460
Field Operations	58,514 [c d]	83,307	-21,941 [d]	61,366	64,400
Subtotal, Science Program Direction	120,491	139,245	-12,339	126,906	142,385
General Reduction for Safeguards and Security	0	-408	408	0	0
Omnibus Rescission	0	-305	305	0	0
Subtotal, Science Program Direction	120,491	138,532	-11,626	126,906	142,385
Pending Budget Amendment	0	0	0	0	2,000 [e]
Total, Science Program Direction	120,491	138,532	-11,626	126,906	144,385
Staffing (FTEs)					
Headquarters (FTEs)	259	284	0	284	284
Field (FTEs)	94	62	+43	105	107
Field Operations (FTEs)	555	732	-176	556	551
Total, FTEs	908	1,078	-133	945	942

Public Law Authorization:
Public Law 95-91, "Department of Energy Organization Act"
Public Law 103-62, "Government Performance and Results Act of 1993"

[a] Includes $603,000 in FY 2000 for Waste Management activities transferred from the Office of Environmental Management in FY 2001. Includes $1,901,000 in FY 2000 and $2,661,000 in FY 2001 transferred from Field Operations to Program Direction for SC site offices. Includes $7,141,000 in FY 2000 and $7,094,000 in FY 2001 for Program Direction related Safeguards and Security (S&S) activities transferred from consolidated S&S program in FY 2002.

[b] Excludes $28,000 in FY 2000 and $30,000 in FY 2001 for S&S activities transferred to consolidated S&S program in FY 2001.

[c] Excludes $362,000 in FY 2000 for S&S activities transferred to consolidated S&S program in FY 2001.

[d] Excludes $19,872,000 in FY 2000 and $21,381,000 in FY 2001 for transfer of Oakland Operations Office to NNSA in FY 2002. Excludes $378,000 in FY 2001 for S&S activities transferred to consolidated S&S program in FY 2001.

[e] A Budget Amendment transferring $2,000,000 from this program will be submitted shortly. The narrative description for this program has already been adjusted to reflect the revised levels.

Funding by Site

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Albuquerque Operations Office					
National Renewable Energy Laboratory	0	120	100	-20	-16.7%
Chicago Operations Office					
Ames National Laboratory	0	0	50	+50	+100.0%
Argonne National Laboratory	602	430	750	+320	+74.4%
Brookhaven National Laboratory	558	420	650	+230	+54.8%
Fermi National Laboratory Laboratory	0	50	100	+50	+100.0%
Princeton Plasma Physics Laboratory	0	110	100	-10	-9.1%
Chicago Operations Office	29,488	31,774	33,046	+1,272	+4.0%
Total, Chicago Operations Office	30,648	32,784	34,696	+1,912	+5.8%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	0	40	100	+60	+150.0%
Idaho Operations Office	0	35	0	-35	-100.0%
Total, Idaho Operations Office	0	75	100	+25	+33.3%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	613	445	750	+305	+68.5%
Stanford Linear Accelerator Center	0	125	150	+25	+20.0%
Berkeley and Stanford Site Offices	2,985	3,130	3,262	+132	+4.2%
Oakland Operations Office	548	0	0	0	0.0%
Total, Oakland Operations Office	4,146	3,700	4,162	+462	+12.5%
Oak Ridge Operations Office					
Oak Ridge Institute for Science and Education	1,120	704	950	+246	+34.9%
Oak Ridge National Laboratory	642	0	0	0	0.0%
Thomas Jefferson National Accelerator Facility	0	45	100	+55	+122.2%
Oak Ridge Operations Office	41,304	43,960	47,265	+3,305	+7.5%
Total, Oak Ridge Operations Office	43,066	44,709	48,315	+3,606	+8.1%
Richland Operations Office					
Pacific Northwest National Laboratory	293	0	100	+100	+100.0%
Richland Operations Office	308	650	800	+150	+23.1%
Total, Richland Operations Office	601	650	900	+250	+38.5%

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Washington Headquarters	42,030	44,868	54,112	+9,244	+20.6%
Subtotal, Science Program Direction	120,491 [a] [b]	126,906	142,385	+15,479	+12.2%
Pending Budget Amendment	0	0	2,000 [c]	+2,000	--
Total, Science Program Direction	120,491	126,906	144,385	+17,479	+1.4%

[a] Includes $603,000 in FY 2000 for Waste Management activities transferred from the Office of Environmental Management in FY 2001. Also includes $7,141,000 in FY 2000 and $7,094,000 in FY 2001 for Program Direction related S&S activities transferred from consolidated S&S program in FY 2002. Excludes $362,000 in FY 2000 for S&S activities transferred to consolidated S&S program in FY 2001. Also excludes $17,971,000 in FY 2000 and $18,720,000 in FY 2001 for transfer of Oakland Operations Office to NNSA in FY 2002.

[b] Excludes $28,000 in FY 2000 for S&S activities transferred to consolidated S&S program in FY 2001.

[c] A Budget Amendment transferring $2,000,000 from this program will be submitted shortly. The narrative description for this program has already been adjusted to reflect the revised levels.

Site Description

Ames National Laboratory

Ames Laboratory (Ames), located in Ames, Iowa, is an integrated part of Iowa State University. Ames was formally established in 1947, by the Atomic Energy Commission, because of its successful development and efficient process in producing high-purity uranium metal in large quantities for atomic energy. Today, Ames pursues a broad range of priorities in the chemical, materials, engineering, environmental, mathematical and physical sciences. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a multi-program laboratory located on a 1,700-acre site in suburban Chicago. Argonne research falls into 4 broad categories: basic science, scientific facilities, energy resources, and environmental management. ANL has a satellite site located in Idaho Falls, Idaho. This site occupies approximately 900 acres and is the home of most of Argonne's major nuclear reactor research facilities. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Berkeley Site Office

The Berkeley Site Office provides institutional program management oversight in the execution of science programs contracted through Lawrence Berkeley National Laboratory and with US industries and universities.

Brookhaven National Laboratory

Brookhaven National Laboratory is a multi-program laboratory located on a 5,200-acre site in Upton, New York. Brookhaven creates and operates major facilities available to university, industrial, and government personnel for basic and applied research in the physical, biomedical, and environmental sciences, and in selected energy technologies. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Chicago Operations Office

Chicago is responsible for the integrated management of its five performance-based contractor laboratory sites--Argonne National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Princeton Plasma Physics Laboratory, and Ames Laboratory; and two government-owned and government-operated federal laboratories--Environmental Measurements Laboratory and New Brunswick Laboratory. Chicago has oversight responsibility for more than 10,000 contractor employees located at various site offices across the Nation. This responsibility includes ensuring the security and environmental safety of the taxpayer's investment--approximately 16,000 acres of land with a physical plant worth approximately $5.8 billion. Chicago is often noted as a leader in both intellectual property matters and management of more than 2,000 active procurement instruments. Several Departmental programs rely on these patent services and the expertise within this Center of Excellence for Acquisitions and Assistance.

Idaho National Engineering and Environmental Laboratory

The Idaho National Engineering and Environmental Laboratory (INEEL) is located on 890 square miles in the southeastern Idaho desert. Other INEEL research and support facilities are located in nearby Idaho Falls. Within the laboratory complex are nine major applied engineering, interim storage and research and development facilities, operated by Bechtel, B&W Idaho for the U.S. Department of Energy. Today, INEEL is solving critical problems related to the environment, energy production and use, U.S. economic competitiveness, and national security. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a multi-program laboratory located in Berkeley, California, on a 200-acre site adjacent to the Berkeley campus of the University of California. The Laboratory is dedicated to performing leading-edge research in the biological, physical, materials, chemical, energy, and computer sciences. The Laboratory also operates unique user facilities available to qualified investigators. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

National Renewable Energy Laboratory

The National Renewable Energy Laboratory (NREL) is located on a 300-acre campus at the foot of South Table Mountain in Golden, Colorado. It is the world leader in renewable energy technology development. Since its inception in 1977, NREL's sole mission has been to develop renewable energy and energy efficiency technologies and transfer these technologies to the private sector. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a multi-program laboratory located on a 24,000-acre site in Oak Ridge, Tennessee. Scientists and engineers at ORNL conduct basic and applied research and development to create scientific knowledge and technological solutions that strengthen the nation’s leadership in key areas of science; increase the availability of clear, abundant energy; restore and protect the environment; and contribute to national security. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Oak Ridge Operations Office

Oak Ridge has oversight responsibility for ORNL, East Tennessee Technology Park (ETTP), Paducah Gaseous Diffusion Plant, Portsmouth Gaseous Diffusion Plant, Y-12 Plant, and the government owned and operated Oak Ridge Institute for Science and Education (ORISE). Oak Ridge has oversight responsibility for more than 15,000 contractor employees located at these sites, as well as responsibility for over 43,000 acres of land and approximately 46,000,000 square feet of facility space, valued at over $12 billion. ORNL has responsibility for the Spallation Neutron Source project (construction began in FY 2000). The Y-12 Plant has recently resumed weapons production operations, and the ETTP is responsible for utilizing DOE assets by recycling metals, the sale of precious metals, and the disposition of uranium. Other major initiatives at Oak Ridge include reducing environmental risk; reducing the Y-12 weapons footprint; re-industrializing the ETTP and some parts of the Y-12 Plant for commercial use; the revitalization of the scientific infrastructure; and creating public and private partnerships for regional economic development. Oak Ridge is also recognized as one of the Department's three Financial Centers of Excellence.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on a 150-acre site in Oak Ridge, Tennessee. ORISE conducts research into modeling radiation dosages for novel clinical, diagnostic, and therapeutic procedures. In addition, ORISE coordinates several research fellowship programs and the peer review of all Basic Energy Sciences funded research. ORISE will now manage and administer ORNL undergraduate research opportunities for students and faculty.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a multi-program laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The Laboratory conducts research in the area of environmental science and technology and carries out related national security, energy, and human health programs. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory (PPPL) is a program-dedicated laboratory (Fusion Energy Sciences) located on 72 acres in Princeton, New Jersey. The primary mission of PNNL is to develop the scientific understanding and the innovations, which will lead to an attractive fusion energy source. Associated missions include conducting world-class research along the broad frontier of plasma science and providing the highest quality of scientific education. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Richland Operations Office

Richland is responsible for and manages all environmental cleanup and science and technology development at the 560 square mile Hanford Site, coordinating closely with contractor companies hired to manage and complete the work of the world's largest cleanup project. The primary contractors are Fluor Daniel Hanford and its subcontractors, the Bechtel Hanford, Inc, the Hanford Environmental

Health Foundation, and the Battelle Memorial Institute, which serves as the contractor for Laboratory operations of the Pacific Northwest National Laboratory. Richland also manages the cooperative agreement with Associated Western Universities to administer research appointments at National Laboratories and universities, for undergraduate students and faculty, as part of the Office of Science funded Education Programs.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center (SLAC) is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California. SLAC is a national basic research laboratory, probing the structure of matter at the atomic scale with x-rays and at much smaller scales with electron and positron beams. SLAC scientists perform experimental and theoretical research in elementary particle physics using electron beams, plus a broad program of research in atomic and solid state physics, chemistry, biology, and medicine using synchrotron radiation. There are also active programs in the development of accelerators and detectors for high-energy physics research and of new sources and instrumentation for synchrotron radiation research. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Stanford Site Office

The Stanford Site Office provides institutional program management oversight in the execution of basic research at the Stanford Linear Accelerator Center, a national laboratory operated under a contract with Stanford University.

Thomas Jefferson National Accelerator Facility

Thomas Jefferson National Accelerator Facility (Jefferson Lab) is a program-dedicated laboratory (Nuclear Physics) located on 273 acres in Newport News, Virginia. Jefferson Lab is a basic research laboratory built to probe the nucleus of the atom to learn more about the quark structure of matter. The Laboratory gives scientists a unique and unprecedented probe to study quarks, the particles that make up protons and neutrons in an atom's nucleus. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Program Direction

Mission Supporting Goals and Objectives

Program Direction provides the Federal staffing resources and associated costs required for overall direction and execution of SC program and advisory responsibilities. Program Direction supports staff in the High Energy Physics, Nuclear Physics, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, Advanced Scientific Computing Research, Multiprogram Energy Laboratories-Facilities Support, and Energy Research Analyses programs, including management, resource, policy, and technical support staff. The staff includes scientific and technical personnel as well as program support personnel in the areas of budget and finance; general administration; grants and contracts; information technology management; policy review and coordination; infrastructure management; construction management; safeguards and security; and environment, safety and health. This program also provides staffing resources at the Chicago and Oak Ridge Operations Offices directly involved in executing SC programs.

Program Direction also includes resources to cover the costs of centrally provided goods and services procured through the Working Capital Fund at Headquarters, such as supplies, rent, telecommunications, desktop infrastructure, etc.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	3,790	3,826	4,036	+210	+5.5%
Travel	214	227	227	0	0.0%
Support Services	160	240	240	0	0.0%
Other Related Expenses	195	309	309	0	0.0%
Total, Chicago Operations Office	4,359	4,602	4,812	+210	+4.6%
Full Time Equivalents	31	37	37	0	0.0%
Berkeley and Stanford Site Offices					
Salaries and Benefits	2,310	2,400	2,532	+132	+5.5%
Travel	121	130	130	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	554	600	600	0	0.0%
Total, Berkeley and Stanford Site Offices	2,985	3,130	3,262	+132	+4.2%
Full Time Equivalents	26	26	26	0	0.0%

	(dollars in thousands, whole FTEs)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Oak Ridge Operations Office					
Salaries and Benefits	2,820	3,633	4,050	+417	+11.5%
Travel	151	163	163	0	0.0%
Support Services	3,446	4,134	5,340	+1,206	+29.2%
Other Related Expenses	1,796	976	976	0	0.0%
Total, Oak Ridge Operations Office	8,213	8,906	10,529	+1,623	+18.2%
Full Time Equivalents	37	42	44	+2	+4.8%
Headquarters					
Salaries and Benefits	30,334	32,878	35,953	+3,075	+9.4%
Travel	1,449	1,514	1,514	0	0.0%
Support Services	5,992	5,350	7,250	+1,900	+35.5%
Other Related Expenses	4,173	4,700	9,205	+4,505	+95.9%
Total, Headquarters	41,948	44,442	53,922	+9,480	+21.3%
Full Time Equivalents	259	284	284	0	0.0%
Total Science					
Salaries and Benefits	39,254	42,737	46,571	+3,834	+9.0%
Travel	1,935	2,034	2,034	0	0.0%
Support Services	9,598	9,724	12,830	+3,106	+31.9%
Other Related Expenses	6,718	6,585	11,090	+4,505	+68.4%
Total, Science Program Direction	57,505	61,080	72,525	+11,445	+18.7%
Total, Full Time Equivalents	353	389	391	+2	+0.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Salaries and Benefits	**39,254**	**42,737**	**46,571**

Supports 391 Full Time Equivalents (FTEs). Enables the Federal staff to provide program guidance and administrative and technical support for a broad spectrum of scientific disciplines and support the Berkeley and Stanford Site Offices and safeguards and security functions at the Oak Ridge Operations Office. In FY 2002, SC will continue to focus on human capital management and planning with the goal of building and sustaining a talented and diverse workforce, offsetting existing and projected shortfalls in the scientific and technical areas, and manage programs and grants in a safe, efficient, and effective manner. **Performance will be measured** based on SC receiving, processing, and coordinating merit peer reviews on 2,000 research proposals; issuing 2,500 procurement actions; and managing 3,500 existing research grants. The funding increase provides for the salary pay raise, increases in personnel benefits, recruitment incentives to attract and encourage scientific and technical experts to accept positions in SC, and 2 FTEs aligned with security responsibilities at the Oak Ridge Operations Office (+$3,834,000).

Travel..	**1,935**	**2,034**	**2,034**

Travel includes all costs of transportation of persons, subsistence of travelers, and incidental travel expenses in accordance with Federal travel regulations.

Support Services...	**9,598**	**9,724**	**12,830**

Provides funding for general administrative and technical expertise (16 percent), information technology (IT) (40 percent), and safeguards and security support (37 percent) within SC and corporate project management efforts in the Department (7 percent). The $3,106,000 increase supports maintaining the current IT infrastructure in Headquarters (+$1,000,000), providing adequate safeguards and security resources at the Oak Ridge Operations Office (+$1,206,000), and SC's contribution to the development of metrics and processes that will improve project management within DOE (+$900,000).

- Continue day-to-day operations within SC, e.g., mailroom operations; travel management; environment, safety and health support; and administering the Small Business Innovation Research program.
- Standardize, integrate, and invest in IT that will best support improved mission accomplishment and promote IT efficiencies consistent with the provisions of the Information Technology Management Reform Act of 1996. SC provides a real-time computer Helpdesk, incorporates new technologies and maintains corporate systems that support grants management, other major business functions, and research setting applications. SC was able to accommodate IT enhancements within existing funding without having to seek new budget authority for improving the electronic operating environment until FY 2002. To continue current operations, an increase of $1,000,000 is requested in FY 2002, for a total of $4,334,000 IT support in Headquarters. The increase enables SC to improve Internet tools and make information and corporate systems accessible from any location around the world; enhance cyber security capabilities; continue planned enhancements; and retire legacy systems – all as outlined in SC's 5-Year Information Management Strategic Plan.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

Performance will be measured monthly through joint review by the business customer(s), Information Management Board, and the Information Management staff responsible for delivering the clearly defined and prioritized products and services. Specifically,

- At least 50 percent of the information management services available through the desktop will be available through remote access.
- Email capability and network systems will be operational and available 99 percent, 24 hours a day.
- Through customer assessments, attain a 75 percent or more rating on productivity improvements directly related to information management enhancements.

■ Support security functions at the Oak Ridge Operations Office, e.g., classifying/declassifying records, processing personnel clearances, securing and handling classified and unclassified information, and providing protective forces to safeguard assets, property, and human resources. The $1,206,000 increase will enable the Oak Ridge Operations Office to acquire the services necessary to maintain a secured environment within the Federal Building and across the Oak Ridge Reservation.

■ Provide funding for the corporate Facility Information Management System (FIMS). FIMS is a web-based application that manages the inventory of the DOE infrastructure management analysis effort. It is one of the many tools used to support the Department's efforts in re-engineering processes and metrics to ensure that facilities and infrastructure are being managed adequately. In FY 2002, funding will support the maintenance and operation of the web-based application, hardware, software, and programmer services. The increase of $200,000 is SC's contribution to maintaining this system.

■ Provide contract support to develop processes, tools, and metrics to ensure that projects are managed adequately. In FY 2002, emphasis will be placed on reforming processes for project management and the acquisition of large facilities throughout the Department to better adhere to project schedules and budgets. The Office of Engineering and Construction Management, within the Office of Chief Financial Officer, will manage a Departmental Project Management Tracking and Control System to monitor the status of projects in terms of cost, schedule, and technical performance. The $700,000 increase is SC's contribution to this corporate effort.

Other Related Expenses	**6,718**	**6,585**	**11,090**

Provides funds for a variety of tools, goods, and services that support the Federal workforce, including acquisitions made through the Working Capital Fund (WCF), computer and office equipment, publications, training, etc. The $4,505,000 increase will support WCF consumption (+$505,000), and Corporate Research & Development (R&D) Portfolio Management Environment (PME) efforts (+$4,000,000).

■ SC will incur new assessments under the WCF. The $505,000 increase will support the increase in cost for rental space, projected increments in usage, and new services, e.g., DOEnet infrastructure, email/video conference capabilities, and more users taking advantage of remote access capabilities.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

- In FY 2002, $4,000,000 is requested to support PME. SC will modernize and streamline the Department's R&D management processes by supporting the design, development and testing of the R&D tracking and reporting module and start defining the specifications for the program execution module. The full PME implementation is to occur in stages over a three-year period. DOE funds a vast amount of energy-related research in several areas and currently lacks a central reliable source to extract the research data. The R&D facilities performing the work follow their own research management processes tailored to their expertise and methods of operation. The information collected and stored to support their management process is often in different formats and at different levels of resolution. This makes the overall management of DOE-funded research a difficult challenge. The PME will become the technology infrastructure, providing information integration methodologies, and process enhancement that will enable electronic cradle-to-grave tracking of research projects, information sharing across programs, and snapshots of the department's R&D. In the end, DOE will improve its management of R&D data, provide a corporate view across the complex, align with applicable laws and report information to Congress.

	FY 2000	FY 2001	FY 2002
Total, Program Direction	**57,505**	**61,080**	**73,525**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2001 vs. FY 2002 ($000)
Salaries and Benefits	
■ Supports the increase in cost-of-living, locality pay, within grades, promotions, and awards for 391 FTEs.	+3,834
Support Services	
■ Maintain the current information technology infrastructure in Headquarters, e.g., Internet tools, cyber security; data recovery, password protection, major business and research setting functions, remote access, etc.	+1,000
■ Provides adequate protection within the Federal Building and across the Reservation in Oak Ridge, Tennessee in line with the work scope and services to be rendered through protective forces, processing personnel clearances, and classifying documents.	+1,206
■ Support the Department's Facility Information Management System.	+200
■ Support the Department's efforts in developing processes, tools, and metrics to insure that projects are being managed adequately.	+700

	FY 2001 vs. FY 2002 ($000)
Other Related Expenses	
■ Supports incremental cost and projected usage of goods and services provided by the Working Capital Fund, e.g., office space, supplies, printing/graphics, DOEnet, email/televideo conferencing, remote access, etc.	+505
■ Support Corporate Research & Development (R&D) Portfolio Management Environment (PME)	+4,000
Total Funding Change, Program Direction	+11,445

Support Services

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Technical Support Services					
Test and Evaluation Studies	800	526	1,426	+900	+171.1%
Total, Technical Support Services	800	526	1,426	+900	+171.1%
Management Support Services					
ADP Support	3,798	4,074	5,074	+1,000	+24.5%
Administrative Support	5,000	5,124	6,330	+1,206	+23.5%
Total, Management Support Services	8,798	9,198	11,404	+2,206	+24.0%
Total, Support Services	9,598	9,724	12,830	+3,106	+31.9%

Other Related Expenses

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Training	105	115	115	0	0.0%
Working Capital Fund	3,545	3,700	4,205	+505	+13.6%
Information Technology Hardware and Software/Maintenance Acquisitions	1,649	1,220	1,220	0	0.0%
Other	1,419	1,550	5,550	+4,000	+258.1%
Total, Other Related Expenses	6,718	6,585	11,090	+4,505	+68.4%

Science Education

Mission Supporting Goals and Objectives

For over 50 years, the Department of Energy and its predecessor agencies have supported science and engineering education programs involving university faculty as well as pre-college teachers and students. In the past, the Department has provided support for university students, pre-college teachers, and college faculty through hands-on research experiences at the Department's National Laboratories and research facilities.

The involvement of DOE's National Laboratories in faculty/student research is perhaps the most distinguishing feature of the agency's participation over the years in math, science, and engineering education. No other Federal agency has an extensive network of research laboratories and facilities as DOE does with its unique physical and human resources. These laboratories and facilities have been the key to the Department's contribution over time to the Nation's math, science, and engineering education goals.

As we enter the new century, the Nation continues to face important challenges related to recruiting and retaining students who have historically been underrepresented (e.g., women, disabled persons, African Americans, Hispanic Americans, and Native Americans) in science and engineering fields. Guided by recent reports such as the National Research Council on Undergraduate Education Achievement Trends in Science and Engineering, the Office of Science will continue to design an undergraduate research fellowship program that couples academic study with extensive hands-on research experiences in a variety of DOE national laboratory settings. This program is intended to enhance the likelihood that underrepresented students will successfully complete their undergraduate studies and progress to graduate school. Historically, over two-thirds of undergraduates who have participated in DOE programs such as this have gone on to graduate school in disciplines directly relevant to the DOE science and technology missions.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Energy Research Undergraduate Laboratory Fellowships	3,002	2,500	2,910	+410	+16.4%
National Science Bowl® Program	550	550	550	0	0.0%
Albert Einstein Distinguished Educator Fellowship Program	204	810	500	-310	-38.3%
Community College Institute of Biotechnology, Environmental Science, and Computing	716	600	1,500	+900	+150.0%
Total, Science Education	4,472	4,460	5,460	+1,000	+22.4%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Energy Research Undergraduate Laboratory Fellowships	**3,002**	**2,500**	**2,910**

The Energy Research Undergraduate Laboratory Fellowship Program (ERULF) is the oldest of the Science Education programs. The ERULF program supports a diverse group of students at our National Laboratories in individually mentored research experiences. Through these unique and highly focused experiences these students will comprise a repository of talent to help the DOE meet its science mission goals. The paradigms of the program are: 1) students apply on a competitive basis and are matched with mentors working in the students' fields of interest; 2) students spend an intensive 10-16 weeks working under the individual mentorship of resident scientists; 3) students must each produce an abstract and formal research report; 4) students attend seminars that broaden their view of career options and help them understand how to become members of the scientific community; 5) program goals and outcomes are measured based on students' research papers, students' abstracts, surveys and outside evaluation. An undergraduate student journal was recently created which publishes selected full research papers and all abstracts of students in the program. The National Science Foundation (NSF) has begun a collaboration with this program as of FY 2001.

The program will ensure a steady flow of students with technical expertise into the Nation's pipeline of workers in both academia and industry. A system is being created to track students in their academic career paths.

A sub-component of the ERULF Program is the Pre-Service Teacher Pilot Program, performed in partnership with the National Science Foundation (NSF). This program brings undergraduate students, who are preparing to become K-12 math, science or technology teachers to the National Laboratories to learn about the world of scientific research through hands-on experiences. Students' performance is measured in the same ways as ERULF students, with the additional component of developing an educational module, under the guidance of a master teacher, which connects their research experiences to the classroom setting.

National Science Bowl Ò Program	**550**	**550**	**550**

SC will manage and support the National Science BowlÒ for high school students from across the country for DOE. Since its inception, more than 60,000 high school students have participated in this event. The National Science BowlÒ is a highly publicized academic competition among teams of high school students who answer questions on scientific topics in astronomy, biology, chemistry, mathematics, physics, earth, computer, and general science. In 1991, DOE developed the National Science BowlÒ to encourage high school students from across the Nation to excel in math and science and to pursue careers in those fields. The National Science BowlÒ provides the students and teachers a forum to receive national recognition for their talent and hard work. Saturday seminars in the latest scientific topics have been added to the National Science BowlÒ weekend. Students participating in the National Science Bowl Ò will be tracked to see the long term impact on their academic and career choices.

(dollars in thousands)	FY 2000	FY 2001	FY 2002
Albert Einstein Distinguished Educator Fellowship Program	**204**	**810**	**500**

The Albert Einstein Fellowship Awards for outstanding K-12 science, math, and technology teachers continues to be a strong pillar of the program for bringing real classroom and education expertise to our education programs and outreach activities. This Congressional initiative, established by the Albert Einstein Distinguished Educator Fellowship Act of 1994, has enabled the Department to maintain an enriching relationship with the Triangle Coalition for Science and Technology Education. The Triangle Coalition administers the program for the Department of Energy through the recruitment, application, selection and placement of the Einstein Fellows and evaluation of the program.

DOE Community College Institute of Biotechnology, Environmental Science, and Computing	**716**	**600**	**1,500**

The DOE Community College Institute (CCI) of Biotechnology, Environmental Science, and Computing was originally a collaborative effort between DOE and its National Laboratories with the American Association of Community Colleges and specified member institutions. Through a recent Memorandum of Understanding with the NSF, students in NSF programs are participating in this program. This program is designed to address shortages, particularly at the technician and paraprofessional levels, in the rapidly expanding areas of biotechnology, environmental science, and computing, that will help develop the human resources needed to continue building the Nation's capacity in these critical areas for the next century. The Institute provides a ten-week research fellowship for highly qualified community college students at a DOE National Laboratory. The paradigms of the program are: 1) students apply on a competitive basis and are matched with mentors working in the students' field of interest; 2) students spend an intensive 10 weeks working under the individual mentorship of resident scientists; 3) students must each produce an abstract and formal research report; 4) students attend professional enrichment activities, workshops and seminars that broaden their view of career options, help them understand how to become members of the scientific community, and enhance their communication and other professional skills; and 5) program goals and outcomes are measured based on students' research papers, students' abstracts, surveys and outside evaluation. An undergraduate student journal was recently created which publishes selected full research papers and all abstracts of students in the program. The National Science Foundation has begun a collaboration with this program as of FY 2001. This will allow NSF's undergraduate programs to include a DOE community college internship in their opportunities provided to students.

Total, Science Education	**4,472**	**4,460**	**5,460**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
■ Under the ERULF, additional students and faculty, including undergraduate students who are preparing to teach math, science or technology, can be supported. The participants will perform research at a DOE National Laboratory or with an industry/business partner. The DOE, through a new Memorandum of Understanding, is partnering with the NSF to provide human resource development through opportunities in DOE National Laboratories.	+410
■ This decrease brings the funding for Einstein Fellowships to the level required to support the on-going level of effort. One-time needs in FY 2001 resulted in an increase in funding not needed in FY 2002 for Einstein Fellowships.	-310
■ Expands the Community College Institute program to more students, including faculty student teams. The DOE is partnering with the NSF in a new Memorandum of Understanding, to provide human resource development through opportunities in DOE National Laboratories for students and faculty participating in NSF programs. These programs will help increase the diversity in the science, math, engineering, and technology fields and serve as a model to other Federal agencies wishing to expand the scientific/technical workforce of the Nation.	+900
Total Funding Changes, Science Education..	+1,000

Field Operations

Mission Supporting Goals and Objectives

The Field Operations subprogram pays the salaries and benefits of the Federal personnel located at the Chicago and Oak Ridge Operations Offices. Consistent with the field restructuring effective October 1, 2000, as part of implementing NNSA, the Oakland Operations Office that was funded in this subprogram in FY 2001, is funded by NNSA in FY 2002. The Chicago and Oak Ridge staff are responsible for managing the daily business, administrative and technical services that support Science and other DOE program-specific work performed within the field and laboratory structure. The following administrative and technical services are provided by this core matrix staff: financial stewardship, personnel management, contract and procurement acquisition, labor relations, legal counsel, public and congressional liaison, intellectual property and patent management, environmental compliance, safety and health management, infrastructure operations maintenance, information systems development and support, and reindustrialization.

In addition, this subprogram provides funding for the fixed requirements associated with rent, utilities, and telecommunications. Other requirements such as information systems support, administrative support, mail services, printing and reproduction, travel, certification training, vehicle acquisition and maintenance, equipment, classified/unclassified data handling, records management, health care services, guard services, and facility and ground maintenance are also included. These infrastructure requirements are relatively fixed. The offices are also responsible for supplying office space and materials for the Office of Inspector General located at each site.

Other operational requirements funded include occasional contractor support to perform ecological surveys, cost validations, and environmental assessments; ensure compliance with Defense Nuclear Facilities Safety Board safety initiatives; abide by site preservation laws and regulations; and perform procurement contract closeout activities. Departmental and programmatic initiatives, as well as regional and congressional constituents, influence these requirements.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	20,121	20,917	22,067	+1,150	+5.5%
Travel	350	400	400	0	0.0%
Support Services	1,500	1,589	1,650	+61	+3.8%
Other Related Expenses	2,954	3,456	3,617	+161	+4.7%
Total, Chicago Operations Office	24,925	26,362	27,734	+1,372	+5.2%
Full Time Equivalents	233	236	236	0	0.0%
Oakland Operations Office					
Salaries and Benefits	548	0	0	0	0.0%
Travel	0	0	0	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	0	0	0	0	0.0%
Total, Oakland Operations Office	548	0	0	0	0.0%
Full Time Equivalents	7	0	0	0	0.0%
Oak Ridge Operations Office					
Salaries and Benefits	26,173	27,704	28,777	+1,073	+3.9%
Travel	200	321	321	0	0.0%
Support Services	2,866	3,004	3,125	+121	+4.0%
Other Related Expenses	3,802	3,975	4,443	+468	+11.8%
Total, Oak Ridge Operations Office	33,041	35,004	36,666	+1,662	+4.7%
Full Time Equivalents	315	320	315	-5	-1.6%
Total Field Operations					
Salaries and Benefits	46,842	48,621	50,844	+2,223	+4.6%
Travel	550	721	721	0	0.0%
Support Services	4,366	4,593	4,775	+182	+4.0%
Other Related Expenses	6,756	7,431	8,060	+629	+8.5%
Total, Field Operations	58,514	61,366	64,400	+3,034	+4.9%
Full Time Equivalents	555	556	551	-5	-0.9%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Salaries and Benefits	**46,842**	**48,621**	**50,844**

Supports 551 FTEs at the Chicago and Oak Ridge Operations Offices. Provides the Federal staff that is responsible for management and administrative functions and services in support of the many different programs, projects, laboratories, facilities, contracts, and grants under their purview. The funding increase supports the Federal pay raise (+$2,223,000). The FTE level is 5 less than appropriated in FY 2001. The FTE reduction is directly related to aligning safeguards and security functions with line management organizations (NNSA and Science) at the Oak Ridge Operations Office.

Travel	**550**	**721**	**721**

Enables field staff to participate on task teams, work various issues, conduct compliance reviews, and perform contractor oversight to ensure implementation of DOE orders and regulatory requirements at the facilities under their purview. Also provides for attendance at conferences and training classes, and permanent change of station relocation, etc.

Support Services	**4,366**	**4,593**	**4,775**

Chicago and Oak Ridge use a variety of administrative and technical assistance services that are critical to their success in meeting the local customer needs. These services include information technology (IT) and routine computer maintenance support, operating communications centers, processing/distributing mail, travel management centers, contract close-out activities, copy centers, trash removal, facility and grounds maintenance, filing and retrieving records, etc. Cost of living for these general administrative services represents an increase of $182,000.

Other Related Expenses	**6,756**	**7,431**	**8,060**

Funds day-to-day requirements associated with operating a viable office, including fixed costs associated with occupying office space, utilities, telecommunications and other costs of doing business, e.g., postage, printing and reproduction, copier leases, site-wide health care units, assessments including records storage, etc. Employee training and development and the supplies and furnishings used by the Federal staff are also included. The $629,000 increase supports several items.

- Fund incremental cost for utility bills and renting the Federal Building in Oak Ridge and the space occupied by the Chicago Operations Office (+$209,000).
- Acquire compatible computer hardware and software at both Chicago and Oak Ridge to support cyclical desktop replacement, standardize and synchronize equipment with SC's operating systems, and IT investment and remote access capability solutions (+$45,000).
- Fund goods and services provided through Working Capital Fund (WCF) (+$46,000).
- Reimbursement for records stored at the National Archives Records storage facility (+$329,000).

Total, Field Operations	**58,514**	**61,366**	**64,400**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2001 vs. FY 2002 ($000)
Salaries and Benefits	
■ Supports the increase in cost-of-living, locality pay, within grades, promotions, and awards, etc., for 551 FTEs. The FTE level is 5 less than FY 2001. The FTE reduction is directly related to aligning safeguards and security functions with line management organizations (NNSA and Science) at the Oak Ridge Operations Office.	+2,223
Support Services	
■ Provides cost of living for general administrative and technical support services	+182
Other Related Expenses	
■ The increase reflects the cost of living associated with essential day-to-day operations, i.e., rent and utility bills, telecommunications bills, computer and office equipment, goods and services under Working Capital Fund, and reimbursement for records stored at the National Archives, etc.	+629
Total Funding Change, Field Operations	+3,034

Support Services

(dollars in thousands)	FY 2000	FY 2001	FY 2002	$ Change	% Change
Technical Support Services					
Economic and Environmental Analysis	0	0	0	0	0.0%
Total, Technical Support Services	0	0	0	0	0.0%
Management Support Services					
ADP Support	1,825	1,915	1,988	+73	+3.8%
Administrative Support	2,541	2,678	2,787	+109	+4.1%
Total, Management Support Services	4,366	4,593	4,775	+182	+4.0%
Total, Support Services	4,366	4,593	4,775	+182	+4.0%

Other Related Expenses

(dollars in thousands)	FY 2000	FY 2001	FY 2002	$ Change	% Change
Training	475	695	695	0	0.0%
Printing and Reproduction	225	436	436	0	0.0%
Rent & Utilities & Telecommunication	4,350	4,625	4,834	+209	+4.5%
Information Technology Hardware, Software, and Maintenance	620	525	570	+45	+8.6%
Working Capital Fund	154	154	200	+46	+29.9%
Other	932	996	1,325	+329	+33.0%
Total, Support Services	6,756	7,431	8,060	+629	+8.5%